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VIDE.TEHNOLĒGIJA. RESURSI

XVI starptautiskās zinātniski praktiskās konferences rakstu krājums
2025. gada 19.–20. jūnijs

3. SĒJUMS

ENVIRONMENT. TECHNOLOGY. RESOURCES

Proceedings of the 16th International Scientific and Practical Conference
June 19th – 20th, 2025

VOLUME III



Rēzekne 2025

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VIDE. TEHNOLOĢIJA. RESURSI. 16. starptautiskās zinātniski praktiskās konferences materiāli. 2025.gada 19.-20. jūnijs. 3.sējums: RTU Rēzeknes akadēmija, Rēzekne, Latvija, 2025. 403 lpp.

ENVIRONMENT. TECHNOLOGY. RESOURCES. Proceedings of the 16th International Scientific and Practical Conference on June 19-20, 2025. *Volume III*: Rezekne Academy of Riga Technical University, Rezekne, Latvia, 2025. pp. 403.

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Online ISSN 2256-070X

Published by RTU PRESS, 2025

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III SĒJUMS SATURS CONTENTS

Education in Engineering Sciences

Sergey Arakelov, Shaxnoza Raximova INFORMATION AND ANALYTICAL COMPETENCES IN THE PROCESSES OF INTELLECTUAL TRANSFORMATION OF TRAINING OF INFORMATION AND LIBRARY SPECIALISTS	15
Andreas Ahrens, Jelena Zascerinska, Julija Melnikova, Parulkumari P. Bhati, Anastasija Bikova, Mihails Zascerinskis EXAMINING ONLINE PLATFORMS OF STEM CENTRES FOR UPPING OUTDOOR STEM EDUCATION IN LATVIA	25
Dace Brizga, Baiba Jansone, Uldis Karlsons, Elīza Hermāne ASPECTS OF COGNITIVE ERGONOMICS IN FORESTRY ENGINEERING EDUCATION	33
Oksana Bulgakova, Inna Savytska, Lesya Zbaravska, Ādolfs Ruciņš, Aivars Aboltins, Andrii Sikora, Valentina Vasileva EDUCATIONAL CONDITIONS FOR FORMATION OF SPECIAL COMPETENCE OF THE FUTURE SPECIALISTS IN AGRICULTURAL ENGINEERING	41
Oksana Bulgakova, Inna Savytska, Lesya Zbaravska, Ādolfs Ruciņš, Aivars Aboltins, Oleksandr Shutyak, Valentina Vasileva MODERN APPROACHES AND FACTORS, CONTRIBUTING TO THE FORMATION OF PROFESSIONAL COMPETENCE OF AN AGRICULTURAL ENGINEER IN THE SPHERE OF LIFE SAFETY	49
Oksana Bulgakova, Inna Savytska, Lesya Zbaravska, Ādolfs Ruciņš, Aivars Aboltins, Valentina Vasileva A SYSTEM OF PEDAGOGICAL SUPPORT FOR THE IMPLEMENTATION OF AN ACTIVITY-BASED APPROACH IN THE TRAINING OF COMPETENT ENGINEERS	55
Ildze Čakāne, Ilze France, Astrida Cirulis READJUSTING FOR DIGITAL TRANSFORMATION: A PRIMARY MATHEMATICS FRAMEWORK	61
Olha Chaikovska, Olga Stoliarenko, Liudmyla Komarnytska, Maryna Voloshchuk WEBQUESTS AS A TOOL FOR DEVELOPING THE PROFESSIONAL COMMUNICATION SKILLS OF FUTURE SOFTWARE ENGINEERS IN AN INCLUSIVE EDUCATIONAL ENVIRONMENT	69
Vihra Dimitrova MODEL OF SUCCESSFUL DIGITAL TRANSFORMATION OF HIGHER EDUCATION INSTITUTIONS	75
Vihra Dimitrova ANALYSIS OF THE MAIN FACTORS FOR THE DIGITALIZATION OF HIGHER EDUCATION	83

Natalia Dmitrenko, Tetiana Fedyk, Nataliia Franchuk, Iryna Shakhina, Olena Podzygun LEVERAGING CHATGPT TO DEVELOP CRITICAL THINKING THROUGH MATHEMATICAL PROBLEM-SOLVING IN ESP CLASSES	91
Natalia Dmitrenko, Olena Podzygun, Tetiana Fedyk USE OF COMICS IN ENHANCING SPEAKING INTERACTION SKILLS OF PROSPECTIVE ENGINEERS IN ESP CLASSROOM	99
Natalia Dmitrenko, Iryna Shkola, Oksana Dubrova, Inna Lobachuk, Olena Malinka ENGINEERING STUDENTS' ENGLISH PROFICIENCY DEVELOPMENT THROUGH AR TECHNOLOGIES	105
Edvins Evarts HISTORY AT SCHOOL – A PREREQUISITE FOR UNDERSTANDING ENGINEERING	111
Imants Gorbāns REMOTE STUDY WORK CHALLENGES AND THE NEW MODEL IN POST-COVID AND PRE-AI ERA	117
Tzvetelin Gueorguiev AUDITING EDUCATIONAL QUALITY MANAGEMENT SYSTEMS - NOW AND IN THE NEAR FUTURE	123
Lyuba Gyurova, Cvetelina Velkova IMPROVING EDUCATION FOR FUTURE MARINE ELECTROMECHANICS THROUGH EXPERIMENTAL ANALYSIS OF HYDROSTATIC PRESSURE IN LIQUIDS USING THE HM 150.05 EXPERIMENTAL UNIT	129
Andrejs Geske, Rita Kiseļova, Olga Pole ACHIEVING EXCELLENCE IN COMPUTATIONAL THINKING: INSIGHTS FROM THE ICILS 2023 STUDY	135
Anatolii Ivanchuk, Stanislav Podolyanchuk, Oksana Marushchak FEATURE OF ENGINEERING TRAINING FOR FUTURE TECHNOLOGY TEACHERS	145
Renata Kondratavičienė, Inga Bertašienė ASSESSING COGNITIVE AND CREATIVITY COMPETENCES IN PRE-PRIMARY CHILDREN BASED ON LANGUAGE EDUCATION ACHIEVEMENTS	151
Neli Kalcheva, Maya Todorova, Ginka Marinova, Firgan Feradov TEACHING LINEAR REGRESSION WITH PYTHON AND EXCEL: METHODS, TOOLS, AND PRACTICAL TASKS	163
Liubov Khomenko, Lesia Matviienko, Serhii Kashuba, Bohdana Saliuk THE POTENTIAL OF SKETCHFAB IN VISUALIZING TECHNICAL PROCESSES IN THE EDUCATIONAL ENVIRONMENT	169
Renata Kondratavičienė DEVELOPING CRITICAL THINKING IN MATHEMATICS LESSONS FOR FOURTH GRADERS	177

Vasyl Kovalchuk, Svitlana Reva, Iryna Volch, Svitlana Shcherbyna, Halyna Mykhailyshyn, Tetiana Lychova ARTIFICIAL INTELLIGENCE AS AN EFFECTIVE TOOL FOR PERSONALIZED LEARNING IN MODERN EDUCATION	187
Vasyl Kovalchuk, Andrii Kovalchuk, Bohdan Vovk, Oleksandr Derevyanchuk, Oleksandr Rozhkov MODEL OF DIGITALIZATION PROFESSIONAL TRAINING OF FUTURE VOCATIONAL EDUCATION TEACHERS	195
Vitalii Kyslitsyn, Liudmyla Liubarska, Anatolii Ostapovets, Volodymyr Umanets, Yuriy Babchuk FEATURES OF THE APPLICATION OF ARTIFICIAL INTELLIGENCE IN THE FORMATION OF CREATIVITY IN THE PROFESSIONAL TRAINING OF TEACHERS	203
Oleksandr Malykhin, Nataliia Aristova, Liudmyla Dybkova USING AI TOOLS FOR PERSONALISING LEARNING IN THE ENGLISH LANGUAGE CLASSROOM: COMPUTER SCIENCE UNDERGRADUATE STUDENTS' PERCEPTIONS	213
Oleksandr Malykhin, Nataliia Aristova, Liudmyla Dybkova DEVELOPING COMPUTER SCIENCE UNDERGRADUATE STUDENTS' COMMUNICATIVE AND SELF-EXPRESSION SKILLS: DIGITAL VS. TRADITIONAL STORYTELLING METHODS	219
Julija Melnikova, Aleksandra Batuchina, Jelena Zascerinska, Andreas Ahrens, Kamilė Kesylė CREATING A PROFESSIONAL DEVELOPMENT PROGRAM TO ENHANCE GENERAL EDUCATION TEACHERS' SKILLS IN APPLYING DIGITAL LEARNING PLATFORMS FOR TEACHING AND LEARNING	225
Vida Navickienė, Birutė Juodagalvienė POSSIBILITIES OF DEVELOPING CREATIVITY THROUGH THE STUDY SUBJECT OF GEOMETRIC MODELLING: STUDENTS' POINT OF VIEW	233
Līga Ramāna, Ingrīda Veilande REFLEXION – A NECESSARY STEP IN THE PROCESS OF SOLVING MATHEMATICS PROBLEMS	239
Karin Robam, Tony Hand, Sander Kanter, Erik Väli ENHANCING MINING EDUCATION: INTEGRATING ONLINE LEARNING AND HANDS-ON EXPERIENCE FOR COMPREHENSIVE SKILL DEVELOPMENT	247
Bohdan Rozputnia, Liudmyla Shevchenko, Volodymyr Umanets, Serhii Yashchuk, Yuliia Sabadosh ARTIFICIAL INTELLIGENCE AS A SUPPORT TOOL IN TEACHING PROGRAMMING TO FUTURE BACHELOR'S STUDENTS OF VOCATIONAL EDUCATION	253
Olha Rymar, Ivanna Bodnar, Nataliia Sorokolit, Olena Khanikiants, Volodymyr Rykhal THE IMPACT OF GAME-BASED TECHNOLOGIES ON THE DEVELOPMENT OF ATTENTION IN YOUNGER SCHOOL-AGE CHILDREN	261
Iryna Shkola, Natalia Dmitrenko, Olena Kondratieva, Iryna Shymanovych, Andrii Moroz GAMIFICATION METHODS FOR DEVELOPING LEXICAL COMPETENCE OF ENGINEERING STUDENTS	269

Inna Savytska, Oksana Bulgakova, Lesya Zbaravska, Ādolfs Ruciņš, Aivars Aboltins, Mykhailo Torchuk, Valentina Vasileva APPLICATION OF THE EDUCATIONAL INFORMATION SYSTEMS IN PROFESSIONAL TRAINING OF AGRICULTURAL ENGINEERS STUDYING PHYSICS	277
Inna Savytska, Oksana Bulgakova, Lesya Zbaravska, Ādolfs Ruciņš, Aivars Aboltins, Iryna Mushenyk, Valentina Vasileva, Valentyna Kulenko APPLICATION OF ARTIFICIAL INTELLIGENCE TO AUTOMATICALLY VERIFY STUDENT CALCULATIONS IN HIGHER EDUCATION INSTITUTIONS	283
Inna Savytska, Oksana Bulgakova, Lesya Zbaravska, Ādolfs Ruciņš, Aivars Aboltins, Mykhailo Torchuk, Valentina Vasileva, Valentyna Kulenko INNOVATIVE TECHNOLOGIES IN TEACHING THEORETICAL MECHANICS FOR AGRI-ENGINEERS	289
Nataliia Saienko, Olena Chevycheova, Inna Ivanova, Anastasiia Ptushka, Svitlana Vorobiova THE USE OF DIGITAL TECHNOLOGIES IN TEACHING CULTURE AND FOREIGN LANGUAGES TO TECHNICAL UNIVERSITY STUDENTS	295
Sigita Saulėnienė, Aurėja Šarkauskaitė, Agnė Gintaraitė DEVELOPMENT OF INFORMATION TECHNOLOGY COMPETENCE IN PRE-SCHOOL AND PRE-PRIMARY SCHOOL TEACHERS DURING THE EDUCATION PROCESS	303
Oleksandra Shykyrynska, Natalia Pakhalchuk, Kateryna Kolesnik, Tetiana Kryvosheya, Inna Karuk PREPARING STUDENTS TO USE VIRTUAL TRAVEL TO DEVELOP PRESCHOOLERS' COGNITIVE INTEREST	311
Oleksandra Shykyrynska, Valentyna Liapunova, Olha Melnykova, Kateryna Mnyshenko, Tetiana Petryshyna TRAINING OF FUTURE SPECIALISTS FOR THE FORMATION OF THE FOUNDATIONS OF MEDIA LITERACY OF CHILDREN OF PRESCHOOL AND PRIMARY SCHOOL AGE	319
Oleksandra Shykyrynska, Liudmyla Ishchenko, Olha Riaboshapka, Viktoriia Kanska, Tetiana Zhuravko ADVANTAGES AND DISADVANTAGES OF DISTANCE LEARNING IN UKRAINIAN HIGHER EDUCATION INSTITUTIONS UNDER MARTIAL LAW	325
Nataliia Sorokolit, Ivanna Bodnar, Olha Rymar, Uliana Shevtsiv, Olha Shymanova-Stefanyshyn DIGITAL APPLICATIONS IN PHYSICAL EDUCATION: EXPERIENCE, BENEFITS, AND IMPLEMENTATION CHALLENGES	329
Feruza Umaralieva, Barno Ganieva, Nadira Usmanova, Jorakhonova Khadicha METHODS OF FORMING ELECTRONIC RESOURCE COLLECTIONS OF ACADEMIC LIBRARIES IN A DIGITAL EDUCATIONAL ENVIRONMENT, CRITERIA FOR SELECTING ELECTRONIC RESOURCES	337
Nadira Usmanova, Barno Ganieva, Feruza Umaralieva, Jorakhonova Khadicha BASICS OF MEDIA LITERACY FORMATION FOR LIBRARY SPECIALISTS	343

Nataliia Vinnikova, Larysa Bondarenko, Anastasiia Karpenko, Iryna Mankovska CHATGPT IN EDUCATIONAL AND SCIENTIFIC ACTIVITIES OF GRINCHENKO UNIVERSITY: A DIAGNOSTIC SECTION	349
Iłona Valantınaitė, Vaida Asakavičiūtė, Živilė Sederevičiūtė-Pačiauskienė FACTORS DETERMINING STUDENTS ACTIVITY IN VIRTUAL DISCUSSION	361
Cvetelina Velkova INTEGRATED LEARNING OF LAMINAR BOUNDARY LAYER MODELING ON FLAT PLATES USING ANSYS WORKBENCH FOR SHIP MACHINERY MECHANICS AND MECHATRONICS SPECIALISTS)	369
Lenina Zadorozhna-Kniahnytska, Oksana Goliuk, Olha Hroshovenko, Larysa Prysiashniuk, Iryna Khadzhynova USAGE OF AN INTERACTIVE ELECTRONIC TEXTBOOK APPLICATION: REFLECTION OF UKRAINIAN EXPERIENCE (BASED ON THE INTEGRATED COURSE “HEALTH, SAFETY, AND WELL-BEING”)	375
Alisa Zakharina, Ievgeniia Zakharina, Nataliia Sorokolit, Iryna Hrybovska, Nataliia Stefanyshyn MULTIMEDIA TECHNOLOGIES IN THE TRAINING OF STUDENTS OF HIGHER EDUCATION INSTITUTIONS IN UKRAINE FOR ANIMATION ACTIVITIES IN THE RECREATION AND WELLNESS SECTOR	383
Iryna Zavadska, Anatolii Skrypnyk, Oksana Palyliulko, Oleksandr Shevchuk, Artur Mykhailyk INTEGRATING HISTORY AND SOFTWARE ENGINEERING: A STEM-BASED APPROACH TO TEACHING	391
Wei Zhang, Dzintra Ilisko AI FOR ENHANCING ENGLISH LESSON DESIGN AND PEDAGOGY IN CHINESE MIDDLE SCHOOLS	397

III

**EDUCATION IN
ENGINEERING SCIENCES**

Information and Analytical Competences in the Processes of Intellectual Transformation of Training of Information and Library Specialists

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Abstract—The article analyzes world experience in creating a new paradigm in the development of information and library education in the digital age. It is proposed to use intellectual educational technologies in teaching information and library disciplines, taking into account the analysis of information and analytical competencies, which can change the quality of the process of training highly qualified specialists for information and library institutions of the republic.

Keywords—*Information and analytical competence, intellectual educational technologies.*

I. INTRODUCTION

In the Concept for the Development of the Higher Education System of the Republic of Uzbekistan until 2030, in the paragraph "Introduction of digital technologies and modern methods into the educational process", in order to introduce digital technologies and modern methods into the educational process, the following activities are proposed: the use of "cloud technologies" in educational processes [1].

The widespread introduction of a system of electronic libraries with the possibility of remote use of them, the expansion of opportunities for continuous improvement of the professional qualifications of students by organizing the use of the library fund and databases after completing their studies at higher educational institutions; acceleration of the creation of national electronic educational resources, organization of work on the translation of foreign electronic educational resources, a gradual increase in the share of electronic resources in the educational process, the creation of electronic educational

literature, as well as a system for placing information on electronic resources in libraries using a QR code in order to download electronic educational literature on mobile devices; creation of an electronic database of scientific and technical information, consisting of materials of conferences, graduation theses, master's and doctoral dissertations of a higher educational institution, the widespread introduction of the use of an anti-plagiarism system in order to preserve the novelty of scientific and technical information in the future, etc.

Purpose of the research. Implementation of intellectual educational technologies in information and library education, taking into account the analysis of information and analytical competence of future specialists.

II. MATERIALS AND METHODS

Methodology of the research. The conducted terminological analysis allowed us to reveal the essence of the information competence of a library specialist - this is a professionally significant personality trait, manifested in the ability to effectively solve social and professional problems using information and communication technologies, improve one's skills in the field of information technology, and adapt professional knowledge to the changing conditions of the information society.

Research methods:

- analysis of pedagogical and specialized literature on the research problem;

Online ISSN 2256-070X

<https://doi.org/10.17770/etr2025vol3.8524>

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- the method of terminological analysis (for the introduction into the research of the concepts of competence and information-analytical competence, hypothesis, theoretical modeling)

Empirical methods: included and remote observation, individual and group conversations; questionnaires, the method of expert assessments, rating methods, interviewing, testing; pedagogical experiment, including ascertaining, forming and control stages; statistical processing of the results.

As a system, information competence includes tasks, functions, properties, has its own characteristics and structure.

The tasks are:

- enrichment with knowledge and skills from the field of informatics and information and communication technologies;
- development of communicative, intellectual abilities;
- implementation of an interactive dialogue in a single information space.

The functions include:

- normative-legal (indicators of achievements and development; it manifests itself as a system of moral norms, norms of a legal nature, which must be followed in the information society);
- epistemological (aimed at the systematization of knowledge, knowledge of the surrounding reality and self-knowledge by a person of himself);
- communicative (ensuring communication in the information society);
- adaptive (adaptation to the conditions of the information society);
- evaluative (assessment of the significance, usefulness of information, etc.);
- developing (formation of an active life position, independence, self-realization on the basis of a certain system of knowledge and norms adopted in the information society).

Properties have the following properties:

- dualism - the presence of an objective (external assessment of information competence by society) and subjective (internal - self-assessment of one's information competence by an individual) parties;
- relativity - knowledge and knowledge bases quickly become obsolete, so they can be considered as new only in a conditionally defined space-time interval;
- structuredness - each person has his own specially organized knowledge bases,

hierarchically ordered into a certain system of knowledge about information, its types, properties, functions and methods of working with it, using information technologies in professional activities;

- accumulativeness - knowledge and knowledge bases tend to "accumulate" over time; newly incoming knowledge is built into existing arrays;
- selectivity - there is a selection of knowledge according to the principle of usefulness, the possibility of practical use in professional activities;
- dynamism - implies that a specialist does not have a significant amount of knowledge, but the ability to constantly update, update at the right time and use them in the process of professional activity;
- integrativity - manifested in the relationship with the socio-cultural environment of a librarian and the development of society as a whole;
- polyfunctionality - the presence of a variety of subject-specific knowledge bases (the semantic component of knowledge bases is multifunctional) allows you to perform many functions that are a factor in the success of the professional development of a librarian.

The peculiarity is that information competence is manifested in:

- self-renewal, application of new forms and ways of meeting the information needs of subjects, adapting information competence to changing conditions;
- self-development, complication of structural, functional and organizational parameters of the entire system of information competence;
- deepening the specialization of individual elements and the level of their interconnectedness and interaction with each other [5].

Researchers of the Continuing Education Laboratory of the National Research University Higher School of Economics, presented the results of the analysis of Russian and foreign recruiting companies. They compared the requirements that are contained in the vacancies for library specialists from analytical databases. In the US, a librarian is an IT specialist. In the group of digital skills of the competence profile of an American librarian, knowledge of 3D printing, statistics, application testing, Big Data, layout, digital curating, SMM, digital and information literacy.

American employers focus on knowledge-intensive and high-tech skills that affect the main areas of activity of a modern specialist: creating libraries and library systems at the national level, participating in consortiums, and developing global perspectives. There is an increased

demand for competencies related to working with clients, holding events [15].

Many scientists dealt with the problem of formation of competencies and competence of specialists. The works of John Raven, Emeritus Professor at the University of Edinburgh, are widely known in the field of diagnostics and research of competence, its assessment and implementation [10]. Of no less interest are the studies of Lyle and Sine Spencer, who developed methods for assessing competence and predicting the results of the work of specialists based on competencies [12]. Also widely known are the works of Edmund Short, who considered competence as a macro concept and identified four approaches to its decoding [11].

The essence of the intellectualization of the library profession is considered by us as the constant acquisition by specialists of relevant library and information knowledge in the process of study or self-education, as well as in increasing the possibilities for their creative implementation in the professional field. Characterized by effective informational thinking and skills that allow to increase the amount of consumed, processed and qualitatively reproduced information, a modern specialist is focused on improving the quality and comfort of user service [5].

In the work of the library director T.A. Kolesnikova reflected "The concept of intellectualization of the library profession and its implementation at the university." The strategic goal of the library is to be the center of integrated information support for educational and scientific processes, as well as cultural activities of the university. The mission of the library is the most effective, comfortable and high-quality satisfaction of the information needs of university communities in study, scientific research, pedagogical and administrative practice [15].

A number of scientists consider information competence as a component of the professional competence of a specialist, they noted the interdependence of computer literacy and professional competence, defining this interaction as a special information literacy, which is updated at the professional level. Information competence reflects different levels of professionalism of the individual, his professional development as a relatively new socio-cultural phenomenon, which is fixed in the regulatory requirements for a modern specialist [8].

Palkevich O. presented for discussion several incarnations of the librarian of the future: librarian and bibliographer 4.0/5.0, information curator and event architect. The position of a new type of bibliographer includes five key competencies: knowledge engineer, local knowledge environment designer, biblio linguist, info set assembler, knowledge archaeologist plus information curator and event architect.

Korshunov I., in turn, noted that an information and library specialist is: an analyst-synthesizer, a creative information navigator, a specialist in the field of digital

technologies, an instructor in the development of information culture, a manager and marketer in the information and library field, etc.

Based on the analysis of discussions in the literature, it can be concluded that the library of the future should evolve into an innovative, intellectual "Library 4.0." In this model, the system will autonomously analyze information and provide users with actionable insights [9]. The role of information and library specialists will become increasingly critical in achieving this vision. Therefore, training for Librarian 4.0 and 5D bibliographers must be prioritized in the near future, particularly in light of the growing intellectualization of information and communication technologies (ICT) [13].

The evolution of Library 4.0 is closely tied to advancements in web technologies (Web 2.0, 3.0, and 4.0) [14], as well as shifting user preferences and reader needs. A library that can adapt to the specific needs of its local community is more likely to be viewed as successful and relevant [9].

Key Components of Library 4.0 Development

The development of Library 4.0 involves several key processes and features:

Intellectual Library: A system capable of analyzing and synthesizing information to provide users with meaningful conclusions.

Makerspaces: Spaces where users can bring ideas to life using modern technologies such as 3D printers, robotics, video game development tools, e-books, and other creative projects.

Context-Aware Technology: Systems that analyze user behavior and interests, enabling the library to adapt its services to changing conditions. This technology allows libraries to recognize users and offer personalized services to both new and existing patrons.

Big Data: Leveraging large datasets to improve services, understand user needs, and enhance decision-making.

Open Source Software: Utilizing open-source tools and platforms to promote flexibility, collaboration, and innovation.

Cloud Services: Employing cloud-based solutions to enhance accessibility, storage, and sharing of resources.

Augmented Reality and Modern Displays: Integrating advanced technologies like augmented reality and interactive displays to create immersive and engaging user experiences.

Librarian 4.0: A new generation of librarians equipped with advanced skills in ICT, data analysis, and user engagement to support the evolving needs of Library 4.0.[18].

In summary, Library 4.0 represents a transformative shift toward a more intelligent, adaptive, and community-

focused library model, driven by cutting-edge technologies and the expertise of next-generation library professionals [16].

The author of the article, based on foreign experience, his own pedagogical experience, observations, student surveys and interviews with teachers, developed a model and matrix of information and analytical competencies, which included the relevant functional features of Library 4.0. Each lesson, during the research period, was conducted using elements of digital technologies and artificial intelligence tools, which brought attractiveness to conducting theoretical and practical classes, as well as increased the level of perception of educational material by students. The results of the study confirmed our assumptions about the effectiveness of the experimental methodological package in the training of future information and library specialists.

Competence can be defined as the integration of knowledge, skills, and attitudes required for effective performance and productivity across various cognitive domains. In this context, knowledge refers to the possession of information or understanding about a subject, skill pertains to the ability to apply that knowledge in practice, and attitude reflects an individual's mental or emotional approach to a task or situation. Within the broader framework of competencies, it is crucial to distinguish between professional competencies, which are specific to a particular job or field, and personal or general competencies, which are applicable across diverse contexts and areas of life.

From one side, the competencies needed by librarians and information professionals can be categorized into six key domains: IT skills, traditional librarianship skills, skills to create value, including research and decision-making skills, transferable and soft skills, communication, management, leadership, learning and coaching, and teamwork skills, appropriate attitude, values and personal qualities, knowledge in the subject area.

From another, research outlines the essential skills for the modern librarian, often referred to as Librarian 2.0. These skills are grouped into seven themes: technology; training and education; research or evidence-based practice; communication; collaboration and teamwork; user orientation; business savvy and personal qualities.

Both frameworks emphasize a blend of technical expertise, traditional librarianship skills, and interpersonal abilities, reflecting the evolving role of librarians in adapting to technological advancements and user-oriented service.

Professional competencies are directly tied to the tasks and operations performed within a specific profession, such as cataloguing, classification, reference services, archiving, and similar activities. On the other hand, personal or transferable skills are more intrinsic and individual in nature, encompassing abilities such as analytical and critical thinking, effective communication, initiative, and a sense of responsibility. These skills

complement professional competencies and enable individuals to perform their roles more effectively. In essence, they are auxiliary skills that interact with professional expertise to enhance job performance [14].

The literature highlights that personal or general competencies are often referred to using various terms, such as transferable skills, general skills, alumni abilities, or core competencies. These terms emphasize the universal applicability of such skills across different roles and contexts, underscoring their importance in supporting professional success and adaptability.

III. RESULTS AND DISCUSSION

Studies indicate that the librarianship market increasingly values personal or soft skills, such as technological proficiency, research capabilities, analytical and critical thinking, and effective communication, over purely professional or technical skills. In today's rapidly evolving digital, cultural, and economic landscape, librarians and information professionals are expected to be versatile, multitasking individuals with a combination of high IQ and EQ. They must possess a diverse skill set to adapt to complex and dynamic environments, essentially becoming "multi-talented jacks of all trades".

While it may not be feasible for a single individual to master all these competencies, the specific skills required often depend on the type of organization and the context in which the librarian or information professional (LIP) works. To be effective, LIP should be equipped with at least a subset of these skills, tailored to the demands of their role and environment.

In dissertation work [8] proposed an alternative vision of the structure of information competence of a library specialist, which includes three components: cognitive, activity-creative and personal-motivational. The percentage distribution by the number of competencies (20% - cognitive component, 65% - activity-creative, 15% - value-motivational) corresponds to the general principle of practice orientation in the credit-modular system of higher professional education [8].

Monitoring of academic groups in the undergraduate direction "Library and Information Activities" of TUIT named after Muhammad al-Khwarizmi among students in the undergraduate direction "Library and Information Activities" (60-3rd year students and 50-4th year students) showed effectiveness (about 36% of average scores, about 28% of high scores) of the competency-based approach in the credit-module system of education and training of future library specialists compared to the traditional (academic) form of education (about 34% of average scores and about 18% of high scores) added optimism to continue active introduction into the learning path of information - analytical competencies, taking into account the processes of intellectualization of ICT.

Analysis of the results of the survey of undergraduates (sample). Questionnaire Questions:

I. What professional competencies would you like to have:

1. Working with public organizations, attracting extra-budgetary funds and resources (PR management, advertising, fundraising, crowdfunding, outsourcing, etc.) – 18%;

2. The use of Machine Learning methods (ML) in the analytical work of the library – 18%;

3. Preparation and implementation of projects – 17%;

4. Working with Big Data in the library (large amounts of various data that require advanced methods and technologies for their collection, storage, distribution, management and analysis) – 13%;

5. Organization of cultural events – 13%.

II. On what knowledge and skills, to the greatest extent, the effectiveness of library work depends:

1. Organizational skills – 33%;

2. Leveraging Library Innovation – 31%;

3. Communication skills, ability to work in a team – 18%;

4. Using Social Media to Advertise Library Activities – 16%;

5. Working with world information resources – 15%.

III. What professional competencies are most important for a modern librarian?

1. Computer Literacy and Information Literacy – 46%;

2. Ability to navigate in the information space (navigation through information resources) – 33%;

3. Willingness to master and implement innovative technologies – 26%;

4. Ability to apply professional knowledge in practice – 24%;

5. Out of the box thinking, creativity – 24%.

IV. In what areas of the library activity do you need additional knowledge:

1. Application of information technology in the library – 23%;

2. Organization of funds and catalogues – 22%;

3. Information and analytical work – 20%;

4. Library statistics – 14%;

5. Reference and bibliographic work – 12%.

On the other hand, diagnostics of the level of information and analytical competence of library specialists of the city information and library system made it possible to identify problem areas in the constituent components of information competence:

- the results of the analysis of data characterizing the cognitive component suggest that 56% of library specialists have theoretical knowledge at a low level; 28% - at an average level and 12% have knowledge at a high level. A weak theoretical basis for librarians was revealed. It is due to the low number of specialists with vocational education (10% higher and 34% secondary specialized education). A special problem is caused by the normative criterion: 45% of the respondents have a low level of right-wing culture. The survey was conducted voluntarily, anonymously, remotely, however, some employees of the city information and library system refused to take part in the survey, which, in our opinion, indicates some psychological barriers in understanding, studying and working with ICT for acquiring and improving information and analytical competence;

- the data characterizing the activity-creative component indicate that the leading place is occupied by such competence as "ownership of applied software", the interdependence of the development of information competence and the creative component is confirmed (51% of respondents confirmed that the growth of information-analytical competence is accompanied by creativity, creativity in the profession);

- the data characterizing the value-motivational component indicate the presence of two basic motives that stimulate the development of information and analytical competence of a library specialist, taking into account the ICT intellectualization process: "improving my professional level", "increasing my own self-esteem".

Factors contributing to the development of information and analytical competence were also identified (availability of good computer equipment; high level of computer proficiency among colleagues; monetary incentives, i.e., external factors for stimulating activities); hindering the development of information and analytical competence (lack of theoretical knowledge; imperfection of computer technology, the inability to update it in the near future; imperfection of methodological work and lack of advanced training courses and retraining of personnel).

Analysis of the results of the survey of managers and employees of the city information and library system (sample).

I. What professional competencies would you like to have:

1. Consulting users and issuing informational certificates "questions - answers" (in traditional and electronic forms) – 52%;

2. Preparation of book exhibitions, days of information, days of a specialist, benefit of the author, book premiere – 43%;

3. Working with public organizations, attracting extra-budgetary funds and resources (PR management, advertising, fundraising, crowdfunding, outsourcing, etc.) – 40%;

4. Creation of multimedia products (training videos, presentations) – 38%;

5. Use of Machine Learning methods (machine learning) in the analytical work of the library – 36%.

II. On what knowledge and skills, to the greatest extent, the effectiveness of library work depends:

1. Leverage library innovation – 95%;

2. Use of Internet resources – 76%;

3. Leadership qualities – 76%;

4. Communication skills, ability to work in a team – 48%;

5. Using social media to advertise library activities – 48%.

III. What professional competencies are most important for a modern librarian?

1. Computer literacy and information literacy – 95%;

2. Willingness to master and implement innovative technologies – 88%;

3. Ability to apply professional knowledge in practice – 57%;

4. Ability to navigate in the information space (navigation through information resources) – 52%;

5. Out of the box thinking, creativity – 50%.

IV. In what areas of the library activity do you need additional knowledge:

1. Reference and bibliographic work – 74%;

2. Application of information technology in the library – 67%;

3. Forms of cultural and leisure work – 48%;

4. Methodical work – 43%;

5. Organization of funds and catalogues – 43%.

Thus, it can be argued that library and information specialists of a new qualification level are gradually acquiring new competencies. They become experts, consultants on the principles of creation, preservation, distribution, management of electronic information resources (EIR) and technological means.

The research results obtained using the competency-based approach and the Case-study method have shown their viability thanks to the implementation of digital learning tools in the educational process, which can be divided into the following types:

- educational software tools, the methodological purpose of which is to communicate the sum of knowledge and skills of educational and practical activities and ensure the necessary level of assimilation established by feedback implemented by

means of software systems (lms.tuit.uz; xn.tuit.uz);

- software tools - simulators designed for practicing skills, educational activities, self-training, they are usually used when repeating or consolidating previously covered material (ILS: IRBIS, ARMAT++, UzNel, DSpase, Omeka);
- programs designed to monitor the level of mastery of educational material - monitoring software (lms.tuit.uz; xn.tuit.uz);
- information-search, information-reference software tools that provide the ability to select and display the information necessary for the user. Their methodological purpose is to develop skills in systematizing information (analytical platforms Scopus, Web of Science, ProQuest);
- simulation software that provides a certain aspect of reality for studying its main structural or functional characteristics using a certain limited number of ILS parameters;
- modelling software tools of arbitrary composition, providing the learner with the basic elements and types of functions for modelling a certain reality. They are intended to create a model of an object, phenomenon, process or situation for the purpose of studying them, studying ILS;
- demonstration software that provides a visual representation of educational material, visualization of the studied phenomena, processes and relationships between ILS objects;

Before the start of the pedagogical experiment, the academic groups were divided into control (CG) and experimental groups (EG) respondents, who showed the following results: excellent - 12% and 14%, good - 44% and 43%, satisfactory - 36% and 32%, unsatisfactory - 8% and 11%. In the experimental group, a competency-based approach was implemented using the Case-study method.

At the end of the pedagogical experiment, the academic groups showed the following results: excellent - 14% and 21%, good - 48% and 52%, satisfactory - 32% and 25%, unsatisfactory - 6% and 2%.

Students have increased interest in digital educational technologies and understanding of the need to acquire new competencies for future professional activities.

Instructional Design. The main emphasis in pedagogical design was on the use of information and communication competencies and the development of future library specialists' professional interest in innovations of digital technologies in the educational process (multimedia resources, collaborative navigation and design, work with analytical platforms, work with automated library and information systems (LIS)), work with educational platforms (moodle.tuit.uz, lms.tuit.uz,

xn.tuit.uz), work with distance learning tools, development of an industry digital library, etc.).

An example of one lesson. During the start of the design, students completed a survey (google.doc), where they showed the level of awareness about information and communication technologies used in libraries and the information and analytical competence required by a modern library specialist.

After this, training in the subject "Information and Analytical Products and Services" was offered using the Case-study method (Case: Scopus is considered by many to be the main competitor of the Web of Science database for citation analysis and journal ranking statistics. The Scopus website states, that the database is "the largest abstract and reference database of peer-reviewed literature and quality web sources using intelligent tools to track, analyze and visualize research." It has more international coverage than web science, and the Scopus interface is simple and intuitive). Next comes the introduction and study of the case by students using information and reference resources. The teacher advises students working in small groups using digital analytical platforms Scopus and WoS, an electronic board, a computer and tablets. Then there is a discussion of the optimality criteria for the proposed options (projector, electronic board). The final part of the lesson: presentation of each group's case (computer, tablets, smartphones, electronic board), tests on the subject and test results (lms.tuit.uz, google.doc, Kahoot).

Innovations in development:

- application of blended learning in the educational process in the training of library personnel using ILS;
- using the Case-study method with digital learning innovations (Zoom, Kahoot, ILS, platforms: Scopus, WoS, Springer);
- development of cases based on real professional scenarios using intelligent ICT

Problems that were solved:

- students' cognitive interest in innovative digital teaching methods has increased,
- the psychological barrier when working with digital technologies was overcome, new knowledge and skills were acquired in using software and hardware devices in the educational process,
- a number of digital innovative technologies used in real library practice have been implemented into the educational process (development of joint Biblio-Pro projects, technologies of the Library 4.0 concept, electronic cataloguing, work with cloud technologies, RFID technologies in libraries).

Current status and general planning of the project:

- currently the preparation of educational and methodological materials, software,

databases for working conditions in Smart Class is underway;

- the experience of innovative work is expanding for the use of intelligent ICT in other educational subjects;
- an analysis of the lessons conducted is carried out for further dissemination of this experience to other courses;
- development of a new ILS with elements of intellectualization of data search in databases is underway;
- the possibility of using the Case-study method using digital technologies for advanced training courses for library workers is being considered.
- Project implementation timeline:
- preparation of syllabuses for courses - 1 month;
- preparation of cases of laboratory work using ILS - 3-4 months;
- preparation of practical training cases using ILS - 3-4 months;
- development and preparation of a textbook and teaching aid for the courses: "Information and analytical products and services" (in Uzbek, undergraduate); "World Information Resources" (in Uzbek, master's degree) - 3-4 years per unit;
- analysis of results - 1 month;
- reports - 1 month.
- The uniqueness of digital technologies and key features of the project:
- use of ILS for students to simulate real production situations in the classroom - cases (with open and closed code);
- the opportunity for students to remotely create electronic resources (electronic libraries, electronic catalogs, full-text information databases, etc.);
- studying a special course based on the Case-study method using digital systems of learning process controllers and intelligent ICT (lms.tuit.uz, xn.tuit.uz, ILS, Kahoot);
- overcoming the psychological barrier among students and teachers in using digital learning tools in the classroom;
- increasing the qualification level of digital competence of teachers;
- quick adaptation of graduates to real work in information and library institutions;
- final qualification work is carried out on a specific production base and using digital technologies (ILS: with open and closed codes).

Summing up the preliminary results of the conducted research, we can state the following: the use of an educational experimental methodological complex in the educational process has improved the quality of the educational process and the final scores based on the

results of student testing. This may later affect the process of improving information and analytical competence and the general training of highly qualified information and library specialists.

IV. CONCLUSIONS

In foreign libraries, there is currently a tendency to single out information learning as an independent direction. You can even see it in the job titles. So, employees who are directly involved in the reference service in the "request-response" mode are called "reference librarians", and employees who train users are "educators". And if earlier informational training of users to search for information was mainly characteristic of academic libraries (university libraries), where it was integrated into training programs as independent courses, now the range of libraries offering training services is expanding, for example, due to public libraries.

At present, the need for user training is determined not only by well-known factors (the educational mission of libraries, the need for users to adapt to the information environment, the obligatory library orientation and bibliographic training), but also by general trends in the development of the information society.

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Examining Online Platforms of STEM Centres for Upping Outdoor STEM Education in Latvia

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Abstract—For addressing the issue of regional inequalities in access to STEM education, the STEM centres are located in Riga, the capital city of Latvia, as well as other cities, namely Cēsis, Liepāja, Sigulda, and Ventspils, established in different regions of Latvia. A visit to a STEM centre in Latvia starts with the investigation of its online platform. The aim of this work is to build a framework for the analysis of online platforms of STEM centres in Latvia. The guiding research questions is: What are functions and sub-functions of online platform of the STEM centre? The descriptive study is employed in this work. The study is aimed at identification of functions and sub-functions of online platforms belonging to STEM centres. In the digital age, online platforms ensure links between STEM centres and their visitors. Online platforms of STEM centres provide important information about STEM centre's aims, functions, facilities, and services. Online platforms also serve as a communication tool (use of emails and similar) between the STEM centre and its clients as well as stakeholders. The theoretical analysis allows shaping the framework for analysis of online platforms belonging to STEM centres. The framework is built of key functions (organisation contact information, educational programmes, and training to services) and sub-functions that online platforms are expected to present. The comparative analysis based on the descriptive study shows that only two online platforms provide the information about all the sub-functions highlighted in the developed framework. Two platforms mostly disclose the sub-functions, and one platform partly covers the necessary information. It should be noted that four

STEM centres that fully or mostly reveal the sub-functions have been supported by Norway grants or belong to Riga Technical University. Our theoretical analysis is limited by the number of existing scientific literature in English. Theoretical analysis in other languages than English may advance further development of online platform for strengthening of STEM education. Another limiting factor is that online platforms were observed by the researchers who took part in this study. Interviews or surveys with the participation of online platforms' users might lead to the creation of a framework with other key functions and subfunctions. Practical implications on a design of online platforms for STEM centres imply that online platforms should be user friendly. Another important aspect is to include all the organisations details such as name, a short description (year of establishment, staff number, etc), address and email, phone number, social media, and location on the map. In regard to educational materials, important is to give open access to the educational materials to all the users. This might increase their interest to visit STEM Centre in person. Another practical implication is to unite the five STEM centres in Latvia in one network and to establish close collaboration between them. This collaboration would support the whole approach to outdoor STEM education, the development of systemic, sequential, and gradual educational materials. This would increase learners' understanding of STEM education as well as sustainable development of Latvia. The links between five STEM centres in Latvia should also be shown on their online platforms.

Online ISSN 2256-070X

<https://doi.org/10.17770/etr2025vol3.8525>

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Keywords—*Science Technology Engineering Mathematics (STEM), STEM centres, online platforms, outdoor STEM education.*

I. INTRODUCTION

In 2027, the labour market in Latvia will lack approximately 14,000 specialists in STEM (Science, technology, engineering and mathematics) fields [2]. However, the supply of STEM-related skills in the Nordic – Baltic region suggests that in this regard Latvia performs the worst in terms of both recent university graduates and working-age population in general [9]. Only about 24% of students choose STEM subjects [1] to study at university level. Therefore, Latvia is facing a challenge of attracting more potential students to study STEM in higher education. This is one side of the problem in STEM education.

Another aspect of the lack of STEM students is that the interest of prospective students to STEM subjects has to be cultivated before the moment when young people are confronted with the choice of a higher education discipline to be studied. Latvia is addressing this issue by establishing STEM centres in different cities of Latvia, e.g. Cesis, Liepaja, Ventspils, Riga, and Sigulda. These five STEM centres are targeted to different age groups: from pre-primary school children to adult education learners.

One more issue with STEM subjects is that some of the STEM disciplines require natural environment. For example, biodiversity observation, or analysis of geographical peculiarities, or birds' watching, or water check, or similar. Outdoor STEM education is beneficial for learners of all ages as it gives freedom to explore, and motivation to learn by becoming more confident [3], [4]. Learners become more involved in STEM education [3], [4]. Learning in the outdoor environment enriches learners' self-discovery process and supplements his or her experience with emotions [14] that are a driving engine in learning and education [16]. In addition to academic knowledge, the outdoors can foster curiosity, communication, social skills and personal experience [14]. For providing a diversity of natural environments, STEM centres were created in three different parts of Latvia, namely Cesis, Liepaja, and Ventspils. These three STEM centres in Cesis, Liepaja, and Ventspils offer outdoor activities in three different natural environments. STEM centre in Cesis offers observation of natural resources, in Liepaja - water and relevant nature, in Riga – wind and geographical landscape for drones and aviation, in Ventspils - healthy lifestyle, human and self-exploration, and geography.

Another aspect of the STEM education is that use of rich geodata and administrative data on Latvia show that 43 percent of youth aged 15 to 18 cannot reach a STEM program within 30 minutes by walking [9]. Estimates of earnings differentials by access time, between program types, and between two modes of travel suggest that children from wealthier families have better access to STEM programs [9]. More densely populated settlements feature better access to STEM programs, as well as better exam results in STEM disciplines [9].

For addressing the issue of regional inequalities in access to STEM education, the STEM centres are located in Riga, the capital city of Latvia, as well as other cities, namely Cesis, Liepaja, Sigulda, and Ventspils, established in different regions of Latvia. A visit to a STEM centre in Latvia starts with the investigation of its online platform.

The aim of this work is to build a framework for the analysis of online platforms of STEM centres in Latvia. The present research intends to provide practical implications on a design of online platforms for STEM centres.

II. MATERIALS AND METHODS

The guiding research questions is: What are functions and sub-functions of online platform of the STEM centre?

The descriptive study is employed in this work. The study is aimed at identification of functions and sub-functions of online platforms belonging to STEM centres.

The descriptive study starts with the analysis of existing theoretical frameworks for online platforms design. Afterwards, five online platforms belonging to existing STEM centres in Latvia will be described. The description of these five online platforms will be based on researchers' interpretation of the available information on these online platforms [6]. It should be highlighted that both versions of online platforms, namely Latvian and English, were analysed. First, the English version of the platform was observed, and, in case of the lack of information, the Latvian version was addressed. The next step of our study will be the comparison of the descriptions of five online platforms. Finally, practical implication on a design of an online platform belonging to STEM centres will be proposed.

III. RESULTS AND DISCUSSION

A. Building a Framework for Analysis

The research devoted to the analysis of online platforms of STEM centres is scarce.

Due to the lacuna in research on online platforms of STEM centres, the study is based on the authors' assumption that online platforms reflect the performance of STEM centres.

It is worth highlighting that STEM centres in Latvia refer to non-formal STEM education. Non-formal education means any organised educational activity outside the established formal system - whether operating separately or as an important feature of some broader activity - that is intended to serve identifiable learning clientele and learning objectives (Coombs, Prosser & Ahmed, 1973). Non-formal education aims to create empowerment opportunities for learners [12].

Hence, building a framework for analysis of online platforms starts from the review of models leveraged for the organisation of STEM centres' work. Our search for model of the organisation of STEM centres' work revealed only two scientific publications. In both publications [11], [10], functions of STEM centres are defined as

- Educational programmes and training;
- Services (networking, infrastructure, resources); and
- Educational research.

It should be noted that online platforms belonging to STEM centres are different from online platforms designed as learning platforms [7]. The difference exists in that learning platforms have such functions as learning analytics, provision of open badges as micro-credentials, and similar [8].

Theoretical analysis of functions of STEM centres as well as observation of online platforms carried out by the authors allow shaping the framework modelling the functions and structure of online platforms belonging to STEM centres.



Fig.1. Framework for analysis of online platforms of STEM centres.

The logics of the framework is based on the analysis of existing research and educational interest of the researchers taking part in this work: from organisation contact information through educational programmes and training to services.

B. Analysis of Online Platforms

B1. STEM Centre in Cesis

Table 1 presents the description of the online platform belonging to STEM Centre in Cesis, Latvia [17].

TABLE 1 ANALYSIS OF ONLINE PLATFORM OF STEM CENTRE IN CESIS

Key function	STEM Centre in Cesis		
	Sub-function	Yes/No	Comment
Organization contact information	Name	Yes	Space Educational Centre
	Description (year of establishment, staff number, etc)	Yes	- Staff photo and relevant emails are shown, - Video presentations
	Address and email	Yes	
	Phone number	Yes	With international code +371
	Social media	Yes	

Key function	STEM Centre in Cesis		
	Sub-function	Yes/No	Comment
Educational programmes and training	Location on the map	No	
	For learners (with age group and educational level)	Yes	For schools
	For trainers	Yes	Including for organizations
Services	Vision, mission, and aim	Yes	To promote children interest
	Visit information	Yes	
	Events	Yes	Including workshops for children, birthday parties

The observation of the online platform reveals that the platform is designed with the use of features conventionally related to the space area, e.g name of the café “Orbita”, a darker colour of the platform associated with the colour of space, the symbol of “rocket” as a mouse indicator, and similar elements.

The platform offers the description of 3 non-formal educational programmes:

- "Living in Space" (4th-6th grade): The purpose of the workshop included in the program is to find out where the Earth is in the universe, what technologies are needed so that we can go to other planets
- "Space Ascension" (classes 7-9): The purpose of the workshop included in the program is to prepare and launch a rocket, using microcontrollers to calculate all the necessary information.
- "Landing on an unknown planet" (classes 10-12): The purpose of the workshop included in the program is to calculate, test and create a system designed to save people on another planet. To do this will require microcontroller programming and testing for data acquisition.

Educational programmes for school children are well structured in accordance with the children age and educational level and described. Exemplary educational materials with open access are available on the platform. The material, activities, resources are described in a good and simple way. Instructions for teachers are available as well. However, learning outcomes could be described, too.

For elementary school teachers, the platform provides the description of the educational programme, namely Education program for professional development of teachers: "Creating a successful interdisciplinary connection between STEM and humanitarian subjects".

For organizations, the Centre offers the simulation "Auseklis" for the development of organizations' staff skills in communication and cooperation.

The Space Educational Centre is an educational leisure and extracurricular destination that offers exploratory experiences for families and school groups. Combining education, hands-on lessons and a popular science approach with a space theme.

The main goal is

- to encourage children's interest in the field of science, technology, engineering and mathematics,
- to offer them a view through the prism of space, and
- to encourage them to connect their future with it.

Interactive exposition of the Centre allows visitor to develop their skills in space exploration, living outside the Earth, physical and mental health of an astronaut, etc.

The STEM centre in Cesis is established with the support of Norway grants.

B2. STEM Centre in Liepaja

Table 2 gives the description of the online platform belonging to STEM Centre in Liepaja, Latvia [18].

TABLE 2 ANALYSIS OF ONLINE PLATFORM OF STEM CENTRE IN LIEPAJA

Key function	STEM Centre in Liepaja		
	Sub-function	Yes/No	Comment
Organization contact information	Name	Yes	Science and Education Innovation Center /ZIIC
	Description (year of establishment, staff number, etc)	Yes	- Staff photo and contact details are shown, -Historical overview is presented
	Address and email	Yes	
	Phone number	Yes	Without international code +371
	Social media	Yes	
	Location on the map	Yes	The Centre has three different locations
Educational programmes and training	For learners (with age group and educational level)	Yes	For schools
	For trainers	Yes	
Services	Vision, mission, and aim	Yes	To arouse children interest
	Visit information	Yes	

Key function	STEM Centre in Liepaja		
	Sub-function	Yes/No	Comment
	Events	Yes	Including workshops for children, birthday parties

The observation of the online platform discloses that the information and the STEM Centre is well structured.

The Centre presents the description of two non-formal educational programmes for children:

- Environmental management for children aged 5 to 10 years,
- Environmental management for children aged 11 to 18.

The educational programmes for children are supported with video materials. Methodical materials with instructions for teachers as well as illustrations are given.

Description of two training programmes for teachers is also shown:

- Ecotechnology for improving the learning process,
- Digital production in education.

However, the detailed description of these two educational programmes for teachers is not available.

The Science and Education Innovation Center offers interactive exhibits. Visitors can try out different technologies and test the laws of nature for themselves. The aim of ZIIC is to use the existing expositions at ZIIC to arouse interest, look for answers, understand them and enjoy the pleasure of cognition.

This STEM Centre has three different facilities in different locations in Liepaja: author street, nature house, and FabLab, co-creation place.

The exposition of the Nature house includes laboratory equipment, models, and laboratory equipment.

The Nature House fosters the skills in becoming bird researcher, quality of water specialist, young geographer, young eco-technologist, young botanist, ant researcher, and protected nature areas.

The STEM centre in Liepaja is established with the support of Norway grants.

B3. STEM Centre in Riga

Table 3 introduces the description of the online platform belonging to STEM Centre in Riga, Latvia [19].

TABLE 3 ANALYSIS OF ONLINE PLATFORM OF STEM CENTRE IN RIGA

Key function	STEM Centre in Riga		
	Sub-function	Yes/No	Comment
Organization contact information	Name	Yes	FUTURIMO
	Description (year of establishment, staff number, etc)	Yes	Staff photo

Key function	STEM Centre in Riga		
	Sub-function	Yes/No	Comment
	Address and email	Yes	
	Phone number	Yes	With international code +371
	Social media	Yes	
	Location on the map	Yes	
Educational programmes and training	For learners (with age group and educational level)	Yes	For schools
	For trainers	No	
Services	Vision, mission, and aim	Yes	To stimulate children interest
	Visit information	Yes	
	Events	Yes	Including boot camps

The observation of the online platform allows finding that the presented information is well organised.

The platform proposes the description of five non-formal educational programmes:

- Little Engineers: Can Newton's Third Law be explained and taught to preschoolers? It can be taught through playing and practical activities with everyday objects, age-appropriate toys and objects around us in nature.
- Engineering Club: A series of practical lessons for high school students, in which they will acquire the skills to independently conduct research in the STEM field, learning physics, electronics, robotics and prototyping.
- Electronics Workshop: A practical cycle of lessons for students, in which they will learn the basics of electrical engineering. They will get an idea of the elements of electrical engineering and electronics, their operation, learn to use various instruments, measuring devices and equipment, solve and analyze electrical engineering problems, evaluate the energy efficiency of equipment, as well as design and develop prototypes.
- Piloting of Unmanned Aircraft (Drones): Nowadays, drones are used very widely - from toys for entertainment to capturing various events in photos and videos, surveying territories and objects, ensuring protection, etc. Even sports competitions are held, where drones reach a speed of 250 km in flight.
- Basics of Aviation Technology: A unique group for aviation enthusiasts, where you can not only gain knowledge about aircraft, their structure, history and achievements, but also try your hand at piloting aircraft using simulators and see with your own eyes the

daily operation of airports by visiting Riga Airport and the training centre of the national airline "airBaltic".

Instructions for teachers as well as textbooks, video materials, and illustration are not available.

The platform does not offer any educational programme for teachers.

The aim of the Centre is to stimulate children's interest in engineering, giving them the opportunity to associate their future profession with it.

The STEM Centre is part of Riga Technical University from Latvia.

B4. STEM Centre in Sigulda

Table 4 highlights the description of the online platform belonging to STEAM Centre in Sigulda, Latvia [20].

TABLE 4 ANALYSIS OF ONLINE PLATFORM OF STEM CENTRE IN SIGULDA

Key function	STEM Centre in Sigulda		
	Sub-function	Yes/No	Comment
Organization contact information	Name	Yes	STEAM Centrs
	Description (year of establishment, staff number, etc)	Yes	Staff information and photo
	Address and email	Yes	The address is not given
	Phone number	Yes	With international code +371
	Social media	Yes	
	Location on the map	No	
Educational programmes and training	For learners (with age group and educational level)	Yes	School children including family members
	For trainers	Yes	
Services	Vision, mission, and aim	Yes	To develop learners' skills
	Visit information	Yes	
	Events	Yes	Including Workshops at schools and educational parties

The online platform is available only in Latvian language.

The online platform offers educational programmes for school children, families and teachers /trainers. However, details about the educational programmes are not revealed.

The STEAM (Science, Technology, Engineering, Art and Mathematics) centre aims at developing students' creativity, critical thinking and problem-solving skills though an innovative and practical approach to learning. It

gives access to modern teaching tools and technologies (virtual reality, fable robots, fun floor, and korbo blocks) for the development of real projects. The centre is a place where students can experiment, collaborate and delve into various topics, from robotics and programming to combining art and design with technology to make a step into the global age of innovation. The STEAM Centre is part of Roboschool.

B5. STEM Centre in Ventspils

Table 5 discloses the description of the online platform belonging to STEM Centre in Ventspils, Latvia [21].

TABLE 5 ANALYSIS OF ONLINE PLATFORM OF STEM CENTRE IN VENTSPILS

Key function	STEM Centre in Ventspils		
	Sub-function	Yes/No	Comment
Organization contact information	Name	Yes	Science Centre VIZIUM
	Description (year of establishment, staff number, etc)	No	
	Address and email	Yes	
	Phone number	Yes	With international code +371
	Social media	Yes	
	Location on the map	No	
Educational programmes and training	For learners (with age group and educational level)	No	
	For trainers	No	
Services	Vision, mission, and aim	Yes	To educate children
	Visit information	Yes	
	Events	Yes	Creative workshops

The online platform is available in Latvian and English languages.

The online platform does not intend visitors' participation in educational programmes.

VIZIUM represents a future city. The Centre has more than 80 interactive and educational exhibits, including creative workshops and science shows to learn science, physics and mathematics, modern technology and programming, healthy lifestyle, human and self-exploration, geography, etc.

At VIZIUM, everyone can step into the shoes of a football player, shooter and snowboarder, experience the force of earthquake, escape from a virtual maze, try on virtual traditional costumes, go on a roller coaster ride, draw in the virtual reality, etc. VIZIUM also offers visiting technical creative workshops and science shows which provide added value to the visit of the Science Centre.

Pre-school children are given an opportunity to play at the Little Explorers Gallery, where everyone including family members can do shopping at a grocery store and refuel using own game bank card, or to become little constructors and play with water attraction.

The Science Centre VIZIUM also offers to climb the 30-metre high observation platform with the spectacular view over Ventspils.

The mission of the Science Centre is to invite and motivate everyone to be interested in, explore and gain knowledge in STEM field, replenishing the formal education with exciting and interactive world exploring experience.

The STEM centre in Ventspils is established with the support of Norway grants.

Modern learners spend most of their learning lives indoors including use of smart devices [14]. The prevalence of indoor learning in Latvia is often impacted by the weather conditions [15]. The period of the school year (autumn - winter - spring) coincides with the coldest time of the year in Latvia [15]. Due to the weather conditions in Latvia, outdoor activities are mostly used as non-formal education. Outdoor learning is a means of expanding and enriching the educational program through outdoor experiences [14]. The implementation of outdoor education ensures [14]

- sensory experience of learners;
- unity of indoor and outdoor environment;
- awareness of the environment as a whole;
- awareness of the importance of promoting sustainable development;
- identifying the interdisciplinarity of the curriculum.

Based on the factors of cold weather conditions in Latvia and global digitalisation, on the one hand, learners become alienated from the natural environment, and, on the other hand their abilities to work with digital devices increase [14].

In digital age, online platforms ensure links between STEM centres and their visitors. Online platforms of STEM centres provide important information about STEM centre's aims, functions, facilities, and services. Online platforms also serve as a communication tool (use of emails and similar) between the STEM centre and its clients as well as stakeholders. Therefore, for the increase of the online platforms' efficiency, it is important to present all the organisation's details, namely organisations' name, a short description (year of establishment, staff number, etc), address and email, phone number with the international code, social media, and location on the map.

In comparison, the previously implemented research highlighted that effective design of STEM platforms is crucial [22]. This includes the use of terminology on STEM platforms understandable for all users [22]. User friendly design of STEM platforms may help engage different stakeholders such as teachers, learners, researchers, experts, computer specialists, cyber security professionals, industrial representatives [22]. That would be

advantageous for the development of STEM platforms. An important feature of online STEM platforms is that they scale STEM instruction with equivalent learning outcomes at lower cost [23].

Our observation of five online platforms belonging to STEM centres in different regions of Latvia allows finding out that each of the STEM centres has its own specialisation:

- Space Educational Centre in Cesis focuses on space related topics including natural resources;
- Science and Education Innovation Center /ZIIC in Liepaja deals with nature, biology, geography, water;
- FUTURIMO in Riga attracts by wind and geographical landscape for aviation and drones training;
- STEAM in Sigulda has the emphasis on built environment by leveraging virtual reality, fable robots, fun floor, and korbo blocks; and
- Science centre VIZIUM in Ventspils represents healthy lifestyle, human and self-exploration, and geography in a city of the future.

The focus of each STEM centre promotes outdoor STEM education from different perspectives (water, air, earth, space, and nature). Therefore, the cooperation between these STEM centres might strengthen visitors' understanding and skills in sustainable development of Latvia.

IV. CONCLUSIONS

The theoretical analysis allows shaping the framework for analysis of online platforms belonging to STEM centres. The framework is built of key functions (organisation contact information, educational programmes, and training to services) and sub-functions reflected in Figure 1 that online platforms are expected to present.

The comparative analysis based on the descriptive study shows that only two online platforms provide the information about all the sub-functions highlighted in the developed framework. Two platforms mostly disclose the sub-functions, and one platform partly covers the necessary information. It should be noted that four STEM centres that fully or mostly reveal the sub-functions have been supported by Norway grants or belong to Riga Technical University.

Our theoretical analysis is limited by the number of existing scientific literature in English. Theoretical analysis in other languages than English may advance further development of online platform for strengthening of STEM education. Another limiting factor is that online platforms were observed by the researchers who took part in this study. Interviews or surveys with the participation of online platforms' users might lead to the creation of a framework with other key functions and sub-functions.

Practical implications on a design of online platforms for STEM centres imply that online platforms should be user friendly. A design of online platform should provide a positive emotional experience to stimulate visitors' curiosity. Another important aspect is to include all the organisations details such as name, a short description (year of establishment, staff number, etc), address and email, phone number with the international code, social media, and location on the map. In regard to educational materials, important is to give open access to the educational materials to all the users. This might increase their interest to visit STEM Centre in person.

Further research will focus on the analysis of experience of online platforms' users. Inclusion of artificial intelligence in online platforms can be studied as well. That might contribute to making online platforms friendly for their users. Comparative studies of online platforms belonging to STEM centres in Latvia and other countries can be helpful for their further advancement. Incorporation of Artificial Intelligence in online platforms of the STEM Centres in Latvia would be an interesting field of investigation. Analysis of scientific literature in other languages than English is an important step in enhancing the framework built within this work.

The research results contribute to the innovation. The innovation is the unity of the five STEM centres in Latvia as one network and the establishment of close collaboration between them. This collaboration would support the whole approach to outdoor STEM education, the development of systemic, sequential, and gradual educational materials. This would increase learners' understanding of STEM education as well as sustainable development of Latvia. The links between five STEM centres in Latvia should also be shown on their online platforms.

ACKNOWLEDGEMENT

The presented work has been carried out within Project NPHZ-2023/10068 "STEMify Your Classroom: STEM Platforms for Quality Education" supported by Nordplus Horizontal 2023 and Project "Mapping Adult Trainers' Qualifications and Competencies in twin transition to SMART future / SMART MAP" supported by Nordplus Adult 2023.

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Aspects of Cognitive Ergonomics in Forestry Engineering Education

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Abstract—one of the most pressing problems in education in Latvia today is to prepare specialists to participate in the labour market and become specialists who respect and ensure occupational safety for those working in the national economy. The study analysed the aspects of cognitive ergonomics for students in the framework of the professional practice of “Motor tools”. Working with a chainsaw can create dangerous situations, significantly endangering a person’s health or even life, as well as affecting his or her working capacity. The well-being of the employee significantly affects the quality and performance of work, because cognitive aspects – fatigue, stress - affect a person’s working capacity. Different methods were used to evaluate the impact of cognitive ergonomics on students’ work abilities: a survey, key indicator method (A, B and C), the method of determining the psychological climate, the method of work ability index, quick exposure check method, expert interviews, as well as the NASA-TLX method. Kendall correlation coefficient calculation methods were used. Work abilities were analysed at the beginning and end of the internship for both full-time and part-time students. The results of the study show that during professional practice students have an increased workload, as well as a significantly increased physical load, causing overload to be possible for individuals with normal physical fitness. Fatigue and reduced performance appear at the end of the practice, especially when it was necessary to make decisions about action in emergency situations. Based on the consensus of experts as characterized by the Kendall correlation coefficient, ($p < 0.05$) cognitive aspects significantly affect a

safe work environment, negatively affecting work productivity and human performance, and response to emergency situations. Currently, due to physical unpreparedness, students often face ergonomic overload caused by a lack of experience and knowledge of work safety, which manifests itself in physical fatigue. Instructors need to pay more attention and point out incorrect or non-ergonomic actions and movements in order to promote a more balanced and safer work environment. As well, students themselves need to pay more attention to their work performance.

Keywords—cognitive ergonomics, engineering education, logging industry, work capabilities.

I. INTRODUCTION

Forestry workers are exposed to work environment risk factors, including the impact of cognitive ergonomics on the performance and health of employees because cognitive ergonomics is related to mental processes: motor response, memory, perception, and reasoning [1]. In line with the International Ergonomics Association's definition of cognitive ergonomics, research analyses mental workload, decision-making, performance quality, human-computer interaction, work stress, and learning effectiveness.

Statistical data indicate that in Latvia in 2022, more than 90% of occupational diseases were related to physical overload, although in 2021, there was a change in work

Online ISSN 2256-070X

<https://doi.org/10.17770/etr2025vol3.8545>

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environment factors from ergonomic risks to psycho-emotional risk factors [2].

A study [3] found that one of the results of stress is increased sleepiness during work and that employees who have been working for more than eleven years are more susceptible, indicating that age plays a significant role.

Cognitively stressful conditions (interruptions, disruptions, and information overload) are associated with impaired task performance and impaired well-being at work, indicating the need to significantly reduce their harmful effects [4], as labour productivity depends on the cognitive abilities of the working person.

The study [5] indicates that there is a lack of cognitive research in the field of ergonomics, employee burnout research, and comprehensive ergonomics and productivity research in the field of logging during the period 2005-2016.

In turn, an analysis of the study conducted from 2014 to 2023 [6] shows that the main logging risk factors found in the studies are related to workload (23%), noise (20%), vibrations (20%), postural load (16%), and musculoskeletal disorders (7%).

In Latvia, there are few studies analyzing work environment risks in the logging industry or the education of these specialists, especially in the context of cognitive ergonomics.

II. MATERIALS AND METHODS

The study was conducted during professional practice, where knowledge of working with a chainsaw was reinforced, including observance of occupational safety procedures, awareness of personal protective equipment and its use, and obtaining a power tool operator's license after passing the exam at the end of the practice.

The location of the internship is Zemgale region, Jelgava municipality, Ozolnieki parish, (MPS) forest research station forest block 58, section 24, narrow-leaved forest, with an area of 1,920 ha and stand composition 10P 130, coordinates of the research object - 56°42'24.8"N, 23°48'08.3"E. As part of the training, main or renewal felling was carried out.

1st year full-time students and 2nd year part-time students participate in the professional internship. The period for part-time students is from 31.07.2023 to 11.08.2023, and for full-time students, it is from 14.08.2023 to 25.08.2023.

In the internship training, 49 students from the full-time group were scheduled, of whom 44 were men, and 5 were women, in the age group 19 to 21 years old. However, one student did not participate in the professional internship training due to health conditions. Of the part-time study program, 35 students were scheduled to participate in the internship, of whom 28 were men, and 7 were women, in

the age group 19 to 43 years old. However, 8 people did not participate in the internship due to personal reasons or health conditions.

To assess the impact of cognitive ergonomics on students' work capacity during the "Motor Instruments" internship, a survey, the main load indicator method (A; B; C), and the psychological climate determination method were used [7]. To determine the interaction of mental and physical workload, the obtained respondent ratings were electronically processed using the NASA – TLX online program [8]. The results of the expert survey were processed using the non-parametric statistical method with Kendall rank correlation, which determines the correlation coefficient W [9], as well as an interactive program for determining (p value) [10]. For more accurate data, non-parametric statistics were also determined – median, mode, and range. Work capacity was analyzed at the beginning and end of the internship for both full-time and part-time students.

III. RESULTS AND DISCUSSIONS

During the "power tool" practice sessions, the instructors observed that students at the beginning of the internship lack theoretical and practical knowledge, which complicates the instructors' work, as they must ensure safety for themselves and others by teaching the basics of work safety, work ergonomics, tree felling, pruning and pruning, as well as ensuring a sufficient level of knowledge so that the students can pass the final exam and obtain a certificate. Students are subjected to a sufficiently high level of stress and hard work that it leads to psycho-emotional and physical burnout.

Since the internship takes place in the summer month of August, regardless of the weather conditions (very hot), the daily schedule must be fulfilled, however, weather conditions have a noticeable impact on the efficiency and duration of work. The work clothes provided are thick, heavy, and for some students do not meet height and size requirements. In hot weather, one can quickly overheat in work clothes, causing intense sweating, which leads to dehydration and fatigue. During the first week of practice, most students experience a strong sense of fear when working with a saw, feel insecure and unsure of themselves, and make many mistakes in violation of work safety regulations. Working in the forest requires great responsibility and precision - you have to make correct cuts and crosscuts, remember warning signals, ensure a safe environment for yourself and those around you, work in a routine, and perform monotonous tasks.

Saw operators have to perform many activities on a daily basis which include lifting, moving and holding, as well as monotonous activities Table 1, which were assessed using the method developed by the Institute for Occupational Safety and Health Protection for assessing ergonomic risks [11].

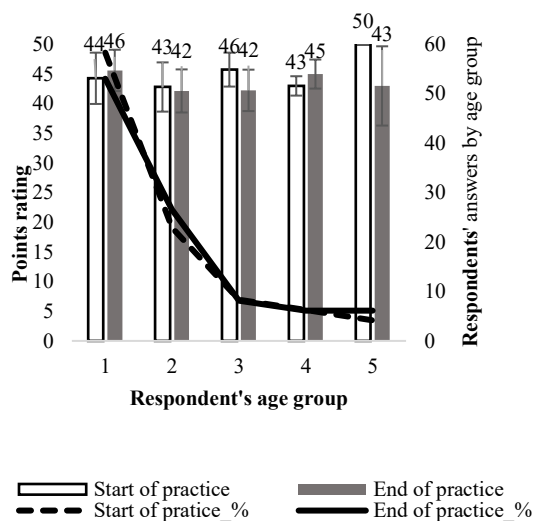
TABLE 1 WORKLOAD RISK LEVEL FOR THOSE EMPLOYED IN THE PRACTICE OF "POWER TOOLS"

Method	Gender		Indicator							Total points	Risk level (I - V)
	Man	Female	Mass (M)	Position (S)	Conditions (A)	Intensity (I)	Accuracy (P)	Organization al conditions (O)	Movement (K)		
SGR-A	M	-	1	2	1	8	-	-	-	32	III
SGR-A	-	F	2	2	1	8	-	-	-	40	III
SGR-B	M	-	1.5	4	2	4	2	-	-	38	III
SGR-B	-	F	1.5	4	2	2	2	-	-	24.7	II
SGR-C	M	-	-	2	1	1	2	0	1	22	II
SGR-C	-	F	-	2	1	1	2	0	1	22	II

It was found that for SGR-A, lifting and moving, which in this case is an electric saw and a petrol chainsaw, both men with 32 points and women with 40 points are exposed to occupational risk group III, which means that the work has a significantly increased physical load, and overload is

reduced working capacity (people younger than 21 or older than 40, as well as those who are not physically fit and people who are sick).

To find out how favourable the psychological microclimate is during the "power tool" practice, a survey



possible for individuals with normal physical fitness. For SGR-B, pushing and rolling assorted firewood, small logs, etc., men are exposed to the III risk group with 38 points, indicating that the weight of the material to be moved is significantly increased and overload is possible for people with normal physical fitness. In turn, women are exposed to risk group II with 24.7 points, which indicates that physical overload is possible for people older than 40 or younger than 21 years of age, as well as for people suffering from diseases. SGR-C, monotonous manual activities (picking branches), both women and men with 22 points are exposed to risk group II, which indicates that the load is increased and overload is possible for people with

was conducted where the answers were provided by 2nd year full-time and 3rd year part-time students. For more detailed results, the respondents were divided into age groups, where 1st group (18 – 20 years); 2nd group (21 – 24 years); 3rd group (25 – 30 years); 4th group (31 – 35 years) and 5th group (36 – 41 years).

The survey results Fig. 1 show that the highest number of responses were submitted by students in the first age group (58.33%), but the least responses were submitted by students in the fifth age group (6.12%). It is also observed that group 1 and group 4 evaluated the first week of practice with a lower score, but the second week of practice with a higher score, which indicates that students were more

dissatisfied with something in the first week of professional practice. For group 2, group 3 and group 5, it is observed that the score was higher in the first week, but lower in the second week.

Fig. 1. Summary of the psychological microclimate among students.

As indicated by the results summarized in the questionnaire, during the internship, 42% of students felt free and without unnecessary stress under the supervision

of instructors, however, 58% of respondents indicated that their stress level was indeed increased.

TABLE 2 PROCESSING THE RESULTS OF THE PSYCHOLOGICAL MICROCLIMATE TEST WITH AN ONLINE INTERACTIVE CALCULATOR

Study program (practicum time)	Respondents, number	Respondents, number	Amplitude, A	Median, M_e	Mode, M_o	Mean
Start of full-time student internship	29	1277	16	44	40	44.3
End of full-time student internship	27	1239	10	46	40	45.9
Full-time student internship in February-March	29	1129	18	38	40	38.9
Part-time student internship begins	12	846	11	43	42; 43	44.5
End of part-time student internship	22	928	16	42	37; 42	42.2
Part-time student student internship in February-March	19	802	11	42	42	42.2

In the results submitted by the students of the full-time study program, Table 2 shows that in the first week of practice, the arithmetic mean or the sum of the average values of the data set is 40.3 points, and in the second week of practice, 45.9, which, according to the values of the point scale, indicates that the psychological microclimate supports a healthy work environment. The results obtained in February - March show that the students' opinion about the psychological microclimate has changed slightly and the average sum of the values is 38.9, which indicates that there were probably disagreements in the work team that had to be resolved.

In the NASA – TLX survey, respondents assessed how low or high the workload is during professional practice. The survey assessed six workload subgroups (mental workload, physical and temporal workload, effort, performance and frustration), the assessment of these factors is based on the work duties performed by students. The aggregated results of full-time and part-time study program students show Fig. 2 that the average workload assessment during professional practice is 57.30 points, which confirms that the workload is increased during professional practice.

During professional practice, it was observed that physical risks the work environment significantly affect the quality of work performance, as the practice takes place in August, the hottest summer month (+27°, +28°). This increased stress and fatigue for students, which was compounded by the noise and vibration caused by the saw. Being surrounded by noise causes fatigue as well as nervousness. During the “power tool” practice, it is mandatory to wear

ear protection, because the noise caused by a gasoline chainsaw reaches 106 decibels (dB), while an electric saw reaches 95 decibels (dB), which means that the noise can be harmful to hearing. Such noise creates difficulties in communicating with teammates, and can also cause changes or disturbances in hearing. Similarly, the vibration caused by the saw increases the stress level, making the student more nervous. Increased vibration can cause a loss of strength. Similar studies have shown that high cognitive load can increase stress, emotional and mental fatigue, reducing students' ability to acquire knowledge as cognitive overload increases [12], therefore it is important to consider options for reducing the load, as it significantly affects outcomes [13].

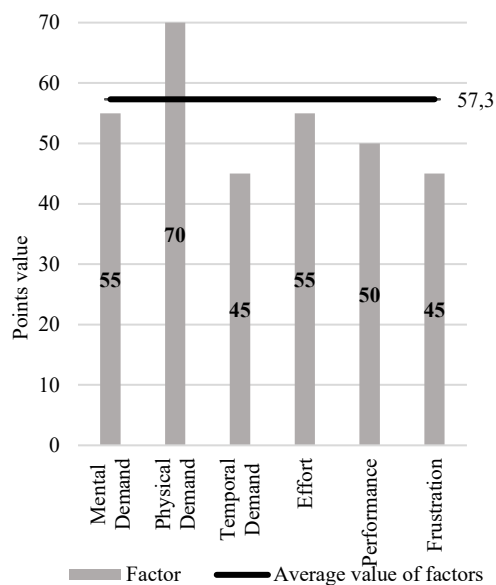


Fig. 2. Assessment of the total workload provided by students.

To assess how cognitive aspects affect students' work capacity and stress, and what improvements should be introduced into the "Power Tools" practice, the study involved 15 experts. from three different sectors: 5 medical experts, 5 occupational safety experts, and 5 forest industry experts. The criteria for selecting experts encompassed education, work experience and experience in their sector (experts' work experience from 5 to 25 years; all experts had higher education). The interview consists of 10 open questions and a point rating which determines the relevance of the question.

Key expert insights:

- Before the internship, students' theoretical knowledge should be tested to determine their level of preparation for the job, while during the internship, a smaller number of students per instructor is needed to allow for longer individual training per student,
- Participating in internships with serious previous injuries can contribute to discomfort, pain, and stress, so a doctor should be

consulted before participating in internships where students may be exposed to increased stress,

- Due to physical unpreparedness, students often face ergonomic overload – due to a lack of experience and knowledge of proper ergonomics - which manifests itself in physical fatigue. Instructors need to pay more attention and correct non-ergonomic actions and movements,
- Before the start of the internship, it is necessary to repeat or undergo first aid or emergency medical care courses, because working with a saw in the forest, a person is exposed to various risk factors,
- Where the employee is exposed to increased workload, it is recommended to perform relaxation exercises every day after work,
- Students of the Forestry Engineering program need to acquire in-depth knowledge of working with a saw (petrol chainsaw, electric saw), because as future direct supervisors, they must be familiar with correct work techniques and occupational safety in logging, forest maintenance, etc.,
- Occupational safety regulations must not be ignored; instructors must respond to and point out mistakes made by students in order to encourage them to recognize and analyse their mistakes,
- Students do not sufficiently respect work safety, which is the result of a lack of work experience, lack of knowledge, youthful maximalism, as well as working in a dangerous work environment, which increases the stress level, causing a person to become careless and insecure.

In order to evaluate the importance rankings of the competence components, the data are summarized in Table 3. The obtained results were subjected to statistical data processing, where non-parametric statistics were determined: mode Mo, median Me and amplitude A.

TABLE 3 RELATIVE IMPORTANCE OF COMPONENTS

Experts	Competency components					Total
	Medicine	Ergonomics	Work safety	Civil protection	Forestry	
A	1	3	2	5	4	15
B	2	3	1	4	5	15
C	3	4	1	5	2	15
D	3	4	1	2	5	15
E	1	4	2	5	3	15
F	4	2	1	5	3	15

Experts	Competency components					Total
	<i>Medicine</i>	<i>Ergonomics</i>	<i>Work safety</i>	<i>Civil protection</i>	<i>Forestry</i>	
G	4	2	1	5	3	15
H	4	3	1	5	2	15
I	2	3	1	5	4	15
J	4	2	1	5	3	15
K	3	2	4	1	5	15
L	1	4	2	5	3	15
M	1	2	3	4	5	15
N	1	3	2	5	4	15
O	3	1	2	5	4	15
Sum of ranks, L_i	37	42	25	65	55	225
Sum of ranks, rank	2	3	1	5	4	-
Median, M_c	3	3	1	5	4	-
Moda, M_o	1	3;2	1	5	3	-
Amplitude, A	3	3	3	4	3	-

The consensus of the importance ranking of the components of the expert survey results was calculated using the Kendall correlation coefficient W and its significance level (1).

$$W = \frac{12 \times S}{m^2 n (n^2 - 1)} = \frac{12 \times 1014}{15^2 \times 5 (5^2 - 1)} = \frac{12168}{27000} = 0.45 \quad (1)$$

Kendall's concordance coefficient $W = 0.45$, its significance level is $p < 0.05$. The survey components are ranked: medicine – 1, ergonomics – 2, occupational safety – 3, civil protection – 4, forestry – 5. By comparing the sums of the L_i ratings, it was found that Table 4.

TABLE 4 CONSENSUS OF EXPERTSURVEY IMPORTANCE RATING

Experts	Competency components					Total
	<i>Medicine</i>	<i>Ergonomics</i>	<i>Work safety</i>	<i>Civil protection</i>	<i>Forestry</i>	
A	1	3	2	5	4	15
B	2	3	1	4	5	15
C	3	4	1	5	2	15
D	3	4	1	2	5	15
E	1	4	2	5	3	15
F	4	2	1	5	3	15
G	4	2	1	5	3	15
H	4	3	1	5	2	15
I	2	3	1	5	4	15
J	4	2	1	5	3	15
K	3	2	4	1	5	15
L	1	4	2	5	3	15
M	1	2	3	4	5	15
N	1	3	2	5	4	15
O	3	1	2	5	4	15
m=15	n=5					
Sum of ranks, L_i	37	42	25	66	55	225

Experts	Competency components					Total
	Medicine	Ergonomics	Work safety	Civil protection	Forestry	
L _i ranks	2	3	1	5	4	-
d _i	22	27	10	51	40	150
d _i ²	484	729	100	2601	1600	5514

The level of significance of medicine and ergonomics is in good agreement, i.e. no significant differences were found ($p = 0.56$). The level of importance of medical and occupational safety is weakly correlated, i.e. no significant differences were found ($p = 0.13$). Very significant differences were found for medical and civil protection assessments ($p < 0.00$). Significant differences were found for medical and forestry assessments ($p < 0.05$). Significant differences were found for ergonomics and occupational safety assessments ($p < 0.04$). Significant differences were found for ergonomics and civil protection assessments ($p < 0.02$). The level of importance of ergonomics and forestry is moderate, or no significant differences are observed ($p = 0.19$). Between occupational safety and civil protection assessments, it was found that there are extremely significant differences ($p < 0.00$). Between occupational safety and forestry assessments, it was found that there are extremely significant differences ($p < 0.00$). The level of importance of civil protection and forestry is moderate coincidence, or no significant differences are observed ($p = 0.30$).

CONCLUSIONS

The results of the study show that during professional practice, students have an increased workload, as well as a significantly increased physical load, where overload is possible for individuals with normal physical fitness. Fatigue and reduced working capacity appear at the end of the practice, especially when it was necessary to make decisions about action in emergency situations. Instructors should offer students stress-relieving exercises that would be used daily to relieve muscle strain. Internships should be held in the autumn-spring period, reducing psycho-emotional risk factors, which are otherwise exacerbated by heat, sweating, overheating, insects, etc.. In adverse weather conditions, one should leave the work environment in a timely manner, without endangering oneself and others.

Further research on the assessment of the logging work environment is particularly relevant, because today's students become the next generation of direct supervisors, who must know correct work techniques and occupational safety practices in logging, forest care, etc.

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Educational Conditions For Formation Of Special Competence Of The Future Specialists In Agricultural Engineering

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Abstract — The article deals with the educational conditions for the formation of special competence of the future agricultural engineering specialists in the process of professionally oriented training in physics. The authors analyse approaches to integrating physical knowledge with professional tasks, relevant to the branch of agricultural engineering, emphasizing the importance to develop in the students a comprehensive understanding of the relationship between the theoretical foundations and the solutions of practical engineering. There is revealed the importance of an interdisciplinary approach in creating educational programs, aimed at the development of the students' ability to apply physical laws and principles in order to solve real problems of production. There are identified the key educational conditions that contribute to the formation of special competence, including: application of problem-oriented learning, aimed at the development of the students' skills in independent analysis of engineering problems and finding solutions; the use of modern technologies for modelling physical processes, allowing for the visualization of complex phenomena and the reproduction of working scenarios of the agricultural engineering activities; the development of critical thinking, ensuring the ability to evaluate and interpret scientific data in a professional context; the formation of teamwork skills, which is important for efficient interaction in production conditions

and solution of complex problems. Particular attention is paid to the digital educational technologies, such as virtual laboratories, digital simulators and software packages that simulate technological processes in the agricultural sector. These tools allow the students to practice engineering skills, to test various models, and analyse their efficiency without the risk of real losses. An impact is assessed in the study of these educational conditions upon the level of training the students in the field of agricultural engineering. The results showed that the use of an integrative approach and digital technologies helps to raise the level of mastery of the educational material by 30–35%, to increase the degree of the students' involvement in the educational process, and develop practical engineering skills. Analysis of academic performance has shown that the students studying in a digital and practice-oriented educational environment are by 40% better at the tasks that require an analytical approach and by 25% faster at adaptation to professional conditions. A conclusion is made that the creation of favourable educational conditions, based on a combination of traditional and innovative teaching methods, can improve the efficiency of professional training of agricultural engineers, ensuring their readiness to solve complex engineering problems, develop innovative thinking and successfully adapt to digital transformations in the agro-industrial complex.

Online ISSN 2256-070X

<https://doi.org/10.17770/etr2025vol3.8544>

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Keywords — *agro-engineering profile, educational conditions, interdisciplinary approach, professional orientation, special competence, training in physics.*

I. INTRODUCTION

Training qualified specialists with developed special competence is one of the priority areas in the field of professional education. Specialists who are ready to efficiently solve professional problems are in demand in the conditions of the modern agro-industrial sector. This requires the introduction of new approaches to teaching that ensure a harmonious combination of theoretical knowledge with practical skills and an emphasis on professionally oriented tasks.

Physics, being the foundation of the engineering education, occupies a special place in the training of the future specialists in agricultural engineering: it provides an understanding of the basic laws of nature, underlying agricultural technologies, and forms scientific and technical thinking.

The accelerated development of the agro-industrial complex necessitates improved training of the personnel for this area, which underlines the relevance of the research topic. Application of innovative educational technologies and the integration of academic disciplines, such as physics, with professional activities make it possible to create conditions for the development of the students' competencies that are necessary for the solution of complex engineering problems. In this context professionally oriented training in physics plays the key role, as it promotes not only an in-depth study of theory but also the development of skills for its application to solve the current problems in the agricultural engineering industry.

Research of the problem of forming professional orientation of training specialists of various profiles is widely presented in the works of the domestic and foreign scientists, involved in pedagogy, psychology, and also in methods of professional education. As a rule, there are considered as the basis the issues of the motives for professional activity, interests and value orientations, pedagogical conditions for training specialists, etc.

Investigations into the problem of development professional orientation for training specialists in various fields have been revealed in the scientific works of Beloev, I. et al. [1], Johnson, D. et al. [2], L. Miller, A., Green, T. [3], Smith, J., Brown, K. [4].

The experience of transforming professional education in the field of agricultural engineering is presented in cases from various countries (Germany, Kenya, India, Canada). Particular attention is paid to the implementation of dual learning, digital technologies and a STEM-oriented approach. The authors [2; 5; 6] analyse the use of digital tools and modelling in teaching engineering disciplines.

Comparison of the traditional and the digital teaching methods, as well as an analysis of the students' academic

achievements after the implementation of digital solutions were made by Taylor, P., Wang, H. [7]. The authors conclude that there is a need for further development of digital tools in the education of agricultural engineering to adapt to the requirements of modern industry. There are considered the key aspects of digitalization of education and its impact upon the learning process, proposing strategies for the integration of online resources, virtual laboratories and interactive platforms into the learning process [8; 9]. Lin et al. consider the importance of professional support and exchange of experience among the teachers for successful implementation of digital technologies into modern education [10].

In their works [11; 12] the authors examine modern teaching methods, aimed at integration of fundamental physical knowledge with the professional training of the future engineers. The authors note the importance of further development of innovative educational methods in the training of the future specialists.

Although the scientific and methodological publications often examine this topic in depth, they often lack a clear plan of action. Therefore, there is a need to develop detailed methodological materials that would regulate the set of methods and teaching tools within a specific discipline. Such materials should not only contribute to the formation and development of professional qualities of the students but also contribute to the solution of current problems. An example of such an approach and its scientific interpretation can be considered in the form of solving specific scientific and production problems [13; 14]. This approach - when the analysis is accompanied by specific recommendations and practical ways of implementation - is the key factor for the improvement of the quality of education.

Within the framework of modern pedagogical discourse, the educational results are most often viewed through the prism of a competency-based approach. From his point of view, the result of training is expressed in the formation of a set of competencies – a kind of “arsenal” of knowledge, skills, abilities and personal qualities – that allows one to act efficiently in various professional contexts. If talking about a future specialist in agricultural engineering, then his special competence means the ability to use academic disciplines (in particular physics), taking into account the current challenges and realities of the sphere of agricultural engineering, as well as the ability to successfully solve a set of technical problems in the process of training and in the future professional activity.

Practice and the research show that the efficiency of professionally oriented teaching of natural science disciplines in universities is directly related to how the main educational blocks are distributed in time: natural science, general professional and specialized disciplines. The linear structure, adopted in the traditional curricula, often makes the students lose interest in their chosen profession. In the early years of study, when the interest is focussed on theoretical courses, many students experience

the lack of a link between the subjects they study and their future professional activities, which leads to a decrease in their motivation and disappointment in the specialty [11].

Bringing the study of natural science disciplines closer to specialized courses allows one to enhance their professional significance, strengthen the students' confidence in the correctness of their choice of profession, and increase their academic motivation. With such an approach natural science and the general professional subjects are perceived not as abstract theoretical courses but as important tools for understanding the key aspects of the specialty. This eliminates an accumulation of the "reserve" knowledge, accelerates its use in professional training and helps the students develop the necessary competencies. In addition, this approach creates conditions for consistent and systematic implementation of the research work which can begin at the early stages of training and be completed within the framework of the diploma project, ensuring the integrity of the educational process and the development of the applied skills. Therefore, the purpose of the conducted study is to identify and substantiate a set of educational conditions that ensure the formation of special competence of the future teachers of the agricultural engineering profile when studying physics in a professionally oriented format.

The research of the efficiency of the new methodology applied the following modern tools: a digital pedagogical experiment with online platforms and educational analytics to assess the quality of the classes, electronic surveys through specialized mobile applications to receive the feedback, analysis of academic performance by using the big data methods and machine learning algorithms to compare the results, remote expert assessment using the video conferencing and online collaboration tools, as well as automated monitoring of the educational process through the tracking systems of the students' involvement.

II. MATERIALS AND METHODS

For efficient formation of special competence, certain educational conditions are necessary which in total will stimulate the students' cognitive interest, ensure a high practice-oriented focus of training and develop the personal qualities of the future agricultural engineers. Let us consider the main conditions in more detail.

A. An interdisciplinary approach

The connection of physics with other disciplines, such as technical mechanics, hydraulics and heat engineering, engineering graphics and computer modelling, agricultural machinery, etc., allows the students to see the practical significance of the phenomena being studied. A link between physics and these disciplines plays the key role in the formation of the students' professional thinking [12].

For example, the study of the law of energy conservation in physics may be associated with the calculation of the efficiency of the internal combustion engines, used in agricultural machinery. The laws of hydraulics find practical application in the design of the

irrigation systems, where exact calculation of the water pressure and flow is required. The knowledge of mechanics is important for the analysis of the load on the components and assemblies of the agricultural equipment, allowing to design more reliable machines. In thermodynamics the students study the heat transfer processes, which finds application in the development of the heat pumps and heating systems for agriculture. Electrodynamics, in turn, helps to understand the operation principles of electric generators and motors that are used in the production of modern agricultural.

Practical classes may include modelling of the irrigation systems, calculation of the parameters of machines and aggregates, analysis of thermal processes in the grain dryers, and designing the energy-saving technologies. For example, application of the knowledge in physics allows optimizing the operation of the drip irrigation system which reduces the water consumption and energy costs. The laboratory experiments, such as studying the strength of materials, are also used in the development and testing of the agricultural machinery.

The integration of physics and professional disciplines develops in the students the skills of an interdisciplinary approach, analytical thinking and the ability to solve real engineering problems. This enhances their readiness for professional activities and increases their motivation to learn. Thus physics becomes not only the theoretical basis but also a tool for achieving practical results in agricultural engineering.

B. Problem-based learning

Setting tasks, based on real professional situations promotes the development of analytical and critical thinking.

For example, the students may be asked to develop a project to optimize the operation of a heat pump for heating a greenhouse, where it is necessary, to calculate the energy costs and efficiency of the system. It is also possible to create models of the operation of the wind turbines which are used to provide agricultural facilities with electricity, with calculations of the efficiency factor and the effect of the wind speed on the energy generation. Another example of the task might concern the design of a grain storage and separation system [15], where the students analyse the heat loss, the temperature distribution within the storage facility, and the energy efficiency of the ventilation system.

The drying chamber is used to remove moisture from various agricultural products, such as grain, vegetables, fruits, herbs and others. Diffusion is the key process that ensures the movement of moisture from the inner layers of the material to the surface, from where it evaporates. Such tasks require that the students applied the knowledge of physics, data analysis, design, and being aware of the consequences of their decisions "Fig. 1".

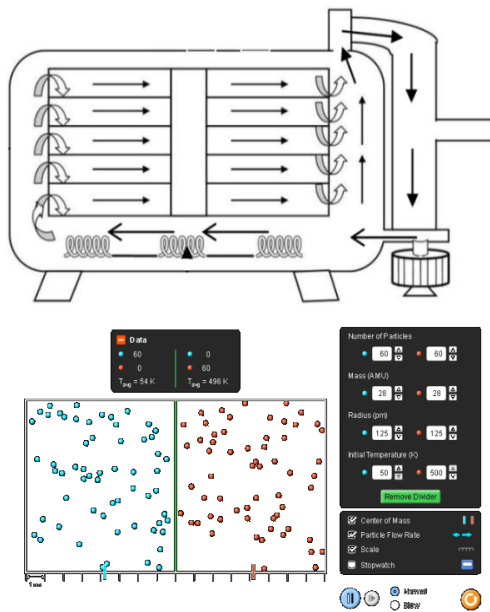


Fig. 1. Setting the tasks, based on real professional situations.

In the process of completing the tasks, the students learn to work in teams, to assign roles, and jointly to seek solutions. In addition, discussing the results with the teacher allows one to evaluate errors, suggest alternative approaches and deepen one's understanding of the material. This method helps to develop not only professional skills but also an ability to solve complex engineering problems, which is the key requirement in the field of agricultural engineering.

C. The use of modern technologies

The introduction of the computer modelling and laboratory work, using digital tools, allows for a deeper understanding of physical processes and their application in agricultural engineering. Computer modelling provides an ability to visualize the complex processes, such as the heat transfer, hydraulics and mechanics, making them easier to understand and analyse. For example, using software, such as MATLAB, SolidWorks, or ANSYS, the students can simulate pumps, the irrigation systems, the heating systems, or the designs of the agricultural equipment, giving them an insight into the behaviour of real objects under different conditions "Fig. 2".

The water pump of a car creates a pressure drop in order to force the coolant to circulate through the engine and radiator. The rotation of the impeller (curved blades of the pump) creates a centrifugal force that increases the kinetic energy of the liquid, causing it to move through the system.

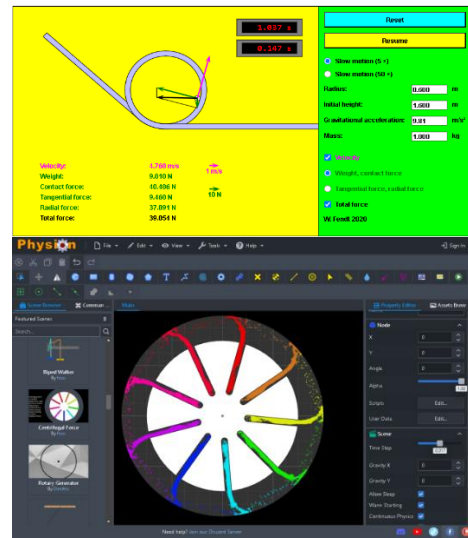


Fig. 2 Computer simulation of the operation of the pump of a car.

The laboratory work with digital instruments allows one to collect accurate data and analyse it with a high degree of detail. Using the temperature, pressure and humidity sensors in educational experiments allows for real-time measurements, which is particularly useful for studying the irrigation or ventilation systems. Virtual laboratories and simulators give the students access to perform complex experiments without the need for expensive equipment. Virtual labs and simulators give students access to perform complex experiments without the need for expensive equipment. Such technologies ensure flexibility and accessibility to learning, especially for the students in remote regions. In addition, the technologies of augmented and virtual reality make it possible to create interactive 3D models that the students can explore while learning about the structure and operating principles of the agricultural equipment. This increases their level of engagement and helps them better understand the theoretical aspects. Thus, the use of modern technologies not only deepens knowledge but also makes the students ready to solve real problems that they will face in their professional activities.

D. The project activities

The work on the projects, related to the solution of current problems in the industry of agricultural engineering, it helps the students develop the teamwork skills and independent search for solutions. Within the framework of such projects the students join into groups to complete the tasks that simulate real-life production situations. For example, one of the tasks might be to develop an automatic soil moisture control system, where the team of students analyse data from the sensors; they develop a control algorithm, and test the prototype. Another project may involve designing an energy efficient agricultural storage system, using modern insulation and ventilation technologies. In the process of implementation of such projects, the participants distribute their roles: someone is responsible for the data collection, someone

else for calculations, and someone for programming or technical assembly.

The work with the project may also involve interaction with the local agrobusinesses, allowing the students to consider real market conditions and requirements. For example, a project to develop a mobile platform for monitoring the crop conditions could involve the use of unmanned aerial vehicles and data analysis, using neural networks. Discussion of the results and feedback from the teachers and external experts help improve the projects and increase their practical value. Such an approach not only develops the technical and analytical skills but also instils in the students a sense of responsibility for the final result, the ability of efficient interaction in the team and adapt to the changing conditions of the task.

III. RESULTS AND DISCUSSION

In the course of the research methodological conditions for the continuity of the formation of physical and technical concepts and their systems were established and formulated as an efficient approach to the implementation of the professional orientation of physics and the formation of special competence of students.

An experimental determination of the implementation efficiency of the designed system of professionally oriented teaching of physics in the formation of special competence of the future agricultural engineers was carried out at the institution of higher education "Podolsk State University" for specialty 208 "Agroengineering". Let us present the results of some experimental sections.

The influence of professionally oriented teaching of physics upon the students' motivation to study this discipline was determined by the comparison of the results of a survey of students (118 people) before studying physics and after their experimental training. At the same time there was determined the level of formation of such a personal factor in the upcoming professional and pedagogical activities of the students as "responsibility". The students were asked to rate on a 10-point scale the level of importance for them of studying physics in their professional and pedagogical training, and therefore in the formation of special competence and responsibility for the choice of the profession they are pursuing. One of the experimental sections revealed the level of development of the students' vision of the manifestation of physical laws in the engineering and technology of agricultural production as a component of special competence (direct connection: physics-engineering) and such a quality as "systematization". At the beginning and end of the physics course the students were given the task of providing a maximum number of examples of the use of physical laws in the industrial and household equipment and technology. The results of the experiment are presented in Table 1.

TABLE 1 DISTRIBUTION OF THE STUDENTS' ANSWERS BY THE NUMBER OF EXAMPLES OF MANIFESTATION OF PHYSICAL LAWS IN TECHNOLOGY

Number of examples	Before training (%) (number of students)	After training (%) (number of students)
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Less than 3 examples	40% (47 students)	15% (18 students)
From 3 to 5 examples	35% (41 student)	40% (47 students)
More than 5 examples	25% (30 students)	45% (53 students)

After the introduction of experiential learning a significant shift was observed in the distribution of the students' responses: the proportion of students who gave fewer than three examples decreased from 40% to 15%, while the proportion of the students who gave more than five examples increased from 25% to 45%. This indicates an improvement in the students' ability to systematize their knowledge and find numerous practical applications of the physical laws, which is an indicator of an improvement in the quality of assimilation of the theoretical material and the development of professional competencies.

The determination of the degree of development of the students' skills to justify the design and operation features of the agricultural machinery units, based on physical laws, as an integral part of special competence (the feedback: technology-physics) and such a skill in their future work activities as "using knowledge in solving professional problems" was carried out through a series of questions, asked to the students before and after experimental training in physics. The assessment of the answers was based on 5 generally accepted quality criteria of answers in pedagogy: correctness, completeness, practical orientation, logicity of the answer, literacy of the presentation, assessed on a five-point scale. The results of the experiment are presented in Table 2.

TABLE 2 DYNAMICS OF DEVELOPMENT OF THE STUDENTS' SKILLS TO SUBSTANTIATE THE DESIGN FEATURES AND OPERATION OF THE AGRICULTURAL MACHINERY UNITS, BASED ON PHYSICAL PHENOMENA AND REGULARITIES

Survey	Average level of the assessment of the responses according to criteria				
	Correctness	Completeness	Practical orientation	Logicity	Literacy of the answer
Before the experimental training	3.6	3.3	3.1	3.0	3.2
After the experimental training	4.0	3.9	4.2	4.1	4.3

Due to experimental learning, the indicators for such criteria as practical orientation, logic, and literacy increased by 1.1 points, and for the rest, on average, by 0.5 points. Such a result demonstrates the high efficiency of implementation of the system of professional orientation of physics in the formation of the students' special competence and an important skill in their future professional activity as "using their knowledge in solving professional problems".

As a result of the study there is noted the positive dynamics in the development of the students' ability to substantiate the design and operation features of the agricultural machinery units, based on physical phenomena and regularities. The systematic study of

physics contributes to the expansion of their knowledge, which is reflected in the increase in the number and quality of the given examples of practical application of the theoretical principles. This confirms that a deep understanding of physics not only deepens the understanding of fundamental laws but also develops skills to analyse and justify the operation of complex technical systems, which is of crucial importance for the future agricultural engineers.

Thus, the results of the experimental studies showed high efficiency in the formation of special competence of the designed and implemented system of professionally oriented training in physics of the future agricultural engineers.

CONCLUSIONS

An experimental determination of the efficiency of the designed system of professionally oriented teaching of physics showed that its implementation significantly increases the motivation of the future agricultural engineers to study this discipline. After the experimental training the students' average scores according to the criteria of practical orientation, logic and literacy increased by 1.1 points, which indicates a significant expansion of their knowledge and skills in applying the laws of physics. These results confirm that the systematic study of physics not only deepens the theoretical basis but also develops critical thinking, it contributes to the formation of a vision of the manifestations of physical laws in the engineering and technology of agricultural production, and also helps to substantiate the features of the design and operation of the agricultural machinery units, which significantly increases the students' professional competence.

Unlike other investigations in which the professional orientation of studying physics was often limited to a general mention of the problems of agricultural engineering, in our work we have developed a holistic teaching system, based on specific examples and scenarios from real agricultural practice. Each topic of the physics course is accompanied by professional cases demonstrating the link between the laws of physics and the operation and maintenance of the agricultural machinery, as well as the models of technological processes. This approach allows the future agricultural engineers not only to acquire theoretical knowledge but also to see immediately its practical significance, to analyse the peculiar features of the devices and operating principles of particular mechanisms, which significantly accelerates the formation of special competence.

Professionally oriented training in physics creates the basis for the formation of special competence of the future agricultural engineers. The introduction of an interdisciplinary approach, problem-based learning and modern technologies allows one to train specialists who are able to apply efficiently the acquired knowledge in their professional activities. Further research may be

aimed at developing new educational technologies and methods that will help improve this process.

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Modern Approaches and Factors, Contributing to the Formation of Professional Competence of an Agricultural Engineer in the Sphere of Life Safety

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Abstract — The article highlights modern approaches and key factors influencing the formation of professional competence of agricultural engineers in the field of life safety. In the context of rapid technological development, digitalization of agricultural production and increased requirements for safe operation of agricultural machinery, the training of specialists requires a comprehensive and multi-level approach. It includes a combination of theoretical training, practical training, digital technologies and active learning methods, aimed at the development of the competencies, required to work in the field of safety. It has been shown that the use of interactive and problem-oriented teaching methods, such as the case-stage method, the discussion method, heuristic questions and paraphrases, semantic echo, mirror and others, integrated into lectures and practical classes in discipline "Life Safety", contributes to a deeper assimilation of the theoretical material. These methods ensure not only the transfer of knowledge but also the development of analytical thinking, the ability to predict risks, make decisions in non-standard situations and work in a team, which is an important component of the professional training of agricultural engineers. There have been identified the key factors, influencing the training efficiency of specialists in this field, including: motivation of the students, based on the awareness of the importance of safety in professional activities; availability of modern

educational resources; the level of qualification of the teaching staff, including the knowledge of innovative educational technologies and practical experience in the field of safety; interaction with employers and specialized organizations, facilitating the implementation of students' project activities and industrial practices in real conditions. Within the framework of the study there is assessed the efficiency of modern approaches to the development of professional competence in the field of life safety. The results showed that the introduction of active learning methods and digital tools increases the assimilation level of the material by 35-40%, increases the students' motivation by 50%, and helps improve the practical skills to predict and prevent risks by 30-45%, compared to the traditional teaching methods. A conclusion is made about the need to create an adaptive educational system that will ensure the formation of sustainable professional competencies of agricultural engineers in the field of life safety. This system should take into account the contemporary challenges, the labour market requirements and ensure the training of specialists capable of risk analysis, making informed decisions and implementing innovative solutions in the field of agricultural engineering.

Online ISSN 2256-070X

<https://doi.org/10.17770/etr2025vol3.8550>

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Keywords — *agricultural engineer, innovative technologies, interdisciplinary approach, professional competence.*

I. INTRODUCTION

The modern agricultural sector faces numerous challenges, in particular the need to ensure a high level of life safety in the production processes. The growing demands for efficiency, environmental friendliness and safety of agricultural technologies require specialists not only to have deep technical knowledge but also the ability to integrate it into complex safety management systems.

The development of professional competence of an engineer in the field of life safety is becoming the key task in the training of highly qualified specialists, capable of working in conditions of global changes and increased risks. The importance of integrating modern technologies, an interdisciplinary approach, active learning and development of systems thinking to solve these problems determines the need to improve the teaching methods.

However, in contemporary conditions when, with the development of technology and the growing number of dangers, the people do not have time to counteract them, with the growth of the cost of the error, with the adaptation of man to danger and violations of the safety requirements, it becomes necessary to form in the graduates of higher educational institutions the requirements for human safety and security. It is the implementation of these requirements that guarantees the preservation of working capacity and health as a high value. Therefore, these requirements must be taken into account when training the graduates for safe actions in the production conditions. For the graduates from the agricultural sector the safety issues are especially relevant due to the high rate of industrial injuries in this sector of economy. The graduates from the higher education institutions with training in engineering are not prepared for professional activities from the safety standpoint. In addition, the lack of a developed need for safety and a propensity to take risks become the conductors of industry-related injuries for them.

The importance of these skills in the modern society has become obvious, which is why it is necessary in the system of higher agricultural education to develop in the students readiness to adequately assess the production situations and timely design safe actions, determined through professional competence in ensuring life safety. This is what determined the topicality of our research.

In the field of professional education there is a tendency towards a transition to the formation of professional competence. Investigations by Woods, D., Carrillo, H., Pingali M., Roberts P., Jovanović, J., Leveson, N., Skjold, T., Tamascelli, N. and others show that in the context of education modernization, professional competence has become the main goal of the educational process in the vocational education institutions.

Several researchers are working to improve the process of teaching safety in universities by studying the development of curricula and teaching methods [1; 2], evaluating the existing process of safety training [3; 7; 8; 12], and discussing the future challenges for safety process training since the agro-industrial complex changes with the introduction of new technologies [4; 5; 9].

In particular, J. Raven interprets competence as an ability, necessary for the successful completion of specific tasks in a particular area, which includes specialized knowledge, professional skills, a certain way of thinking and awareness of the responsibility for one's own actions [10]. Patriarca, R., et al. study the concept and practice of an integrated approach to the analysis and prevention of emergency situations in various industries [11]. It is assumed that the development of professional orientation depends on the development of basic cognitive and effective-motivational inclinations, such as professional knowledge and beliefs [6, 13]. Tamascelli, N. et al. consider the meta-learning approach as a learning tool, based on the analysis of major accidents [14]. The authors examine how organizations can systematically collect and integrate data from the past accident events to gain valuable insights into the improvement of the safety management.

Despite the extensive analysis of this problem in the scientific and methodological works, there are often no specific recommendations for its solution. This underlines the need to develop methodological materials that detail the system of the teaching methods and tools within a particular discipline. The machine and labour safety is formed at the design stage and in the study of their operational characteristics. Therefore, to form the educational materials of the discipline, it is advisable to use modern technical solutions and research in the industry where the future specialist will work [15-17]. Such materials should contribute to the development of professional qualities of the students and efficiently solve the existing problems. The development of such practical recommendations is the key stage in the process of improving the educational process. Therefore, the aim of the study is to develop and substantiate modern approaches, methods and conditions that contribute to the formation of professional competence of engineers in the field of life safety. Achieving this goal will allow one to create a comprehensive system for training engineers that meets modern challenges and ensures a high level of professional competence in the field of life safety.

The following research methods were applied in the work: digital analysis of literature, regulatory documents using specialized academic databases, empirical methods, including online surveys, virtual interviews and automated observation using educational analytics; experimental methods based on digital pedagogical experiments and testing; statistical methods based on data analysis and machine learning algorithms, as well as practice-oriented approaches using simulation and modelling educational platforms. This comprehensive approach ensured the

reliability and practical significance of the obtained results.

II. MATERIALS AND METHODS

In contemporary conditions, when technology is developing and the number of dangerous cases is growing, the people do not manage to counteract them. With the growing cost of the error, with the adaptation of the people to dangerous instances and violations of the safety requirements, it becomes necessary to develop in the graduates of higher education institutions an understanding of inseparable unity of efficient professional activity with the requirements for human safety and security. It is the implementation of these requirements that guarantees the preservation of the working capacity and health as the highest value. Therefore, these requirements should be taken into account when preparing the university graduates for safe actions under the production conditions. For the graduates of agricultural universities, the safety issues are especially relevant due to the high rate of industrial injuries in this sector of economics. The graduates of higher education institutions with a training in engineering are not prepared for professional activities from a safety standpoint. In addition, the lack of a developed need for safety and a propensity to take risks becomes a conductor of industrial injuries.

Taking into account the existing social prerequisites for the formation of professional competence in ensuring life safety, manifested in the state policy, an increase in the level of industrial injuries, an expansion of the range of hazards and determination of the society's social order, factors were identified that hinder the formation of professional competence in ensuring life safety. Among them are adaptability and disregard for dangers, which are manifested in a tendency to take risks and violation of the motivational foundations of activity. Low level of proficiency in the theoretical foundations of safety, which manifests itself in the implementation of industrial risks, insufficient development of the life safety skills, manifested in inability to apply the knowledge depending on the need of a situation and, as a consequence, violation of the orientation-activity foundations of safety. Accordingly, the essence of the concept of professional competence in ensuring life safety, its structure was determined in the form of a motivational component (motives, needs, values), a cognitive component (knowledge), an activity component (skills, possessions, abilities) and a personal component (professionally important qualities) [12]. The listed components of professional competence in ensuring life safety were characterized by indicators of formation by levels. A distinctive feature of the formation of professional competence in ensuring life safety is the mandatory presence of its component integrity, in the form of an integral indicator – “safe behaviour strategy” (Table 1).

TABLE 1 COMPONENTS, INDICATORS AND METHODS FOR THE DEVELOPMENT OF PROFESSIONAL COMPETENCE IN ENSURING LIFE SAFETY

Component	Indicators	Diagnostic tools
Motivational	Awareness of the priority of ensuring safety when performing various types of activities; propensity to take risks; formation of the educational and cognitive component	Methodology for assessing the “hierarchy of personal needs” according to A. Maslow; method for assessing the “degree of readiness for risk” by A.M. Schubert; method for assessing educational motivation (A.A. Rean, V.A. Yakunin).
Cognitive	Knowledge of the basics of safe existence in a dangerous world; professional safety orientation in the context of the profession; ability to analyze from a safety perspective	Test of Intelligence Structure (TSI) by T. Amthauer; testing (achievement tests); method of diagnostic situations.
Activity-based	Ability to identify the safety of working conditions; knowledge of safe action methods; ability to predict from a safety perspective	Assessment method “ability to predict” (L.A. Regush); testing (achievement tests); Method of diagnostic work (case assignments, essays, presentations)
Personal	Readiness to apply solutions in problematic situations in the presence of a threat to life and health, manifested in professionally important qualities: initiative, persistence, determination	Methodology for assessing volitional personality traits (M.V. Chumakov); method for assessing mental activation, interest, emotional tone, tension, comfort (L.A. Kurgansky)

The course of lectures of the discipline was carried out using the following organizational forms: the dialogue method (lecture-conversation); the discussion method (lecture-discussion); the visualization method (lecture-visualization); the problematic presentation method (problematic lecture); the case method (lecture on the analysis of specific situations) [1].

A lecture – a discussion on the topics of “Legal bases of production” and “Organizational bases of safety at work”; a lecture – visualization on the topics of “Harmful substances in the air of the working area”, “Technical means of ensuring labour safety at work”, “Ensuring safety when exposed to noise, vibration, radiation in the production conditions”, “Fundamentals of ensuring electrical and fire safety”; a lecture in a problematic presentation on the topics of “Ensuring a comfortable microclimate of industrial premises”, “Industrial lighting”, “Sanitary and hygienic requirements for general plans,

industrial utility rooms of enterprises”; a lecture – for two on the topic of “Safety in the field of the agro-industrial complex”.

A program for the development of the professional competence in safety, in the form of a theoretical block of the discipline “Life Safety”, made it possible to form an indicator, determined by the totality of knowledge of the basics of safe existence in a world of dangers, and professionally safe orientation of the future professional activity. The ability to analyze was developed throughout the entire training period. In all forms of the theoretical training a case method was used with an analysis of particular security situations. Application of this method made it possible to develop the students’ analytical capabilities, the presence of which was confirmed as the formation of risks of targeted thinking. It is no coincidence that the cases are called a “snapshot of reality” (live situation). In research, the cases are used in a wide range from the printed versions – (situation – problem, situation-assessment), to multimedia – (situation – illustration).

This method took into account the levels of development of the security problems. At the same time, it is impossible to form a level of consciousness for training those who are capable to assess global problems from the position of the existing risk.

It is for this reason that the range of case assignments was gradually expanded. However, the transition was done from the level of security problems at the enterprise level – the micro level, due to the security problems of a regional nature – the meso level, to the level of global problems – macro level, if necessary, and mega level.

To develop risk-oriented thinking a discussion method was used as a method. Discussion as a method of an event is multifaceted. In the experiment it was purposefully used in the lecture classes or as a technique in other methods (in the second block in practical classes during the facilitation support of the educational process, as well as during brainstorming or in the game modeling). A characteristic feature of this method in the experiment was the comparison (dialogue – communication) or opposition (dialogue – dispute) of the positions of those discussing the security issues. That is why this method allowed one to obtain a whole range of results: as a visible result – this is the receipt and generation of new information. And also the taking particular decisions by the students, that is, diagnostics and correction of the problem from the position of safety – this is an increase in the motivation for one's own strengths, getting rid of egoistic thinking, stimulating creativity, the desire to get to the bottom of the truth.

However, a discussion is impossible without asking questions. For this reason, a correctly asked question allowed the audience, whether it was a lecture or practice, to come to some of their own conclusions, based on one's conviction. during the course of study of “Life Safety”. In this case the term “correctness” implied timeliness since the moment of asking the question (namely, “giving”)

made it possible to guarantee successful activation of the audience. However, we did not forget that the untimeliness of the question could also cause an opposite reaction – misunderstanding and passivity. In order the questions asked had successful application, they were applied during the experiment in accordance with their classification possibilities. For example, in the experimental group, open-ended questions were used: “What might happen if at the production facility where you are the director...”? Next, in accordance with the topic being studied, a mini (micro) incident was described, and the student was asked to provide an explanation. If the goal was to consolidate some material, then it made sense to ask questions, to call for a deeper and more detailed answer, an analysis, including: “Explain to us how and why you will act if in your production...”. “How” implies the knowledge of the algorithm of action, and “why” – analysis of the situation. As a result, by reflecting, the student actively participates in the process of cognition.

The redirected questions allowed in the study of the dialogical form of communication to move to the polylogical one. To be or not to be in this discussion – this was solved in the experiment situationally, that is, the teacher decided how much of it was needed in the particular moment of learning. If a discussion was required, then it made sense to develop it; if there was no time or sense, then it was necessary to restrain the audience, that is, to control it. The redirection was effected through the form of a statement: “What do your classmates think about this”? If the goal was to direct the question not to the audience but to the student, then it had a slightly different form of address: “What is the opinion on this issue of...” the surname, name and patronymic of the participant in the audience is called.

The questions to establish the feedback allowed in this period of the experiment to track this link: “If I understand you correctly, you meant...”. Then essence of the substantive conversation was briefly outlined. In addition, the student is forced to go to the next method, that is, a question with a closed limb but also with the right to choose, since he must choose between “yes” or “no”.

The implementation of the selected didactic methods during the period of formation of the professional competence in ensuring the safety of life activities made it possible to form the degree of readiness for professional activity from the standpoint of safety. The student's readiness is assessed through the indicator of the professional competence in ensuring life safety through the involvement of each of the components of the professional competence being formed. With a total implementation of all the above methods, the subject develops an independent strategy of behavior in any situation from the position of safety.

III. RESULTS AND DISCUSSION

In the research the process of conducting the experimental work on the formation of a professional

competence in ensuring life safety was made in the direction 208 “Agroengineering” of the institution of higher education “Podolsk State University”. The number of participants in the groups was: CG – 53 people; EG – 54 people. The aim of the experimental work was to test the efficiency of implementation of the developed methodology for the formation of the professional competence in safety in the process of professional training at the university.

In the research the indicator of the formation of the professional competence in ensuring the safety of life of an engineer is presented in the form of component integrity at the levels: executive, managerial, strategic.

The analysis of the development of the professional competence at the start of the experiment by components allowed one to draw the following conclusions:

- the knowledge that the students have in the context of security is fragmented and not deep enough;
- the motivational foundations that could compensate for the lack of knowledge are not developed to a sufficient level;
- the skills, knowledge and abilities that could guarantee safety in activities are poorly or partially developed;
- professionally important qualities appear episodically or are in an “embryonic” state.

The purpose of the next stage of the pedagogical experiment was to test the efficiency of the model for the development of the professional competence in ensuring life safety, taking into account a set of identified pedagogical conditions, correlated with the methods, forms and means. During the experimental work, a 90-hour course was implemented, conditionally divided into parts: theoretical, practical and independent work. The goal of each lesson was a complex development of the professional competence in ensuring life safety. Within the framework of the research there were used individual, group and collective forms of lectures and practical classes. The results of collective activity were assessed, based on a diagnostic work, which influenced the activity component of the competence. Accordingly, the students gained experience in the context of their profession but without industrial risks they mastered the methods of improving life safety.

At the control stage of the experimental work the efficiency of the proposed model for the formation of the professional competence in order to ensure life safety was assessed by the components and by the integral indicator. The summary data of the ascertaining and control stages of the research by components are presented in Table 2.

The data, presented in Table 3, show positive changes in the components of the professional competence in order to ensure life safety at stages of the experiment. In the control group the following changes occurred in the components: the motivational component changed by 5.0% (from 0.61 to 0.66); the cognitive component – by 4.0% (from 0.73 to 0.77); the activity component – by 5.0% (from 0.81 to 0.86), and the personal component – by 2.0% (from 0.62 to 0.64). In the experimental group more significant changes occurred: the motivational component increased by 20.0%, the cognitive component by 24.0%; the activity component by 22.0%, and the personal component by 19.0%.

TABLE 2 SUMMARY DATA BY THE LEVELS OF FORMATION OF THE COMPONENTS OF THE INTEGRAL INDICATOR OF THE PROFESSIONAL COMPETENCE IN ENSURING LIFE SAFETY

Components (levels) of the professional competence in security	Before the experiment		After the experiment	
	CG	EG	CG	EG
Motivational (unconscious, conscious, justified)	0.61	0.64	0.66	0.84
Cognitive (reproductive, productive, creative)	0.73	0.71	0.77	0.95
Activity-based (elementary, algorithmic, independent)	0.81	0.78	0.86	1.00
Personal (episodic, fragmentary, optimal)	0.62	0.63	0.64	0.82

The data, presented in Table 3, indicate that positive changes occurred in the control and the experimental groups. However, before the start of the experimental work the control and the experimental groups did not have reliable differences, and after the experimental work on the formation of the professional competence in order to ensure life safety, reliable differences were observed in all the indicators characterizing the motivational, cognitive, activity, and personal components.

IV. CONCLUSIONS

Thus the results of the experimental work indicate both quantitative and qualitative changes in the indicators of the formation of the professional competence in order to ensure life safety. It follows from this that these changes are due to the introduction of the formation model, which confirms the purpose of the investigation.

Efficient training of the engineers in the field of life safety requires the creation of an adaptive educational system that combines theoretical and practical training, digital technologies and active methods, such as the case methods, discussions and heuristic questions. These approaches promote in-depth acquisition of the material, development of critical thinking, the risk forecasting skills, and making justified decisions. Important factors are the students' high motivation, availability of modern educational resources, qualified teachers who use innovative methods and have practical experience, as well as close interaction with employers and specialized organizations.

Comparison of the obtained results with the investigations by other authors confirms the tendency to increase the efficiency of professional training using digital educational technologies and interactive methods. In contrast to other studies our research focuses on professionally oriented teaching, taking into account the specifics of the engineering industry, which allows not only to develop general competencies but also to train specialists, capable of risk analysis and implementation of innovative solutions in real production conditions.

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A System of Pedagogical Support for the Implementation of an Activity-Based Approach in the Training of Competent Engineers

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Abstract— The article substantiates the theoretical and methodological foundations for the introduction of an activity-based approach to training competent engineers when studying a course of physics. Contemporary requirements of the agro-industrial complex require integration of the fundamental knowledge with practical skills, which makes this approach the key element of the educational process when studying a course of physics. There are considered the concepts and principles of teaching, aimed at the development of professional thinking, the ability to make decisions in non-standard situations and efficient work with digital technologies, when studying the course of physics. There are identified the pedagogical tools that promote the development of critical thinking, independence and continuous self-development of the students in the process of mastering physics. Methodological recommendations are provided for the creation of a productive educational environment, including interaction with agro-industrial enterprises and individualization of learning when studying the physics course. An analysis of the implementation of the activity-based approach showed its efficiency: the average score of the students in the experimental group increased by 15–20%, and the success rate of completing the practical assignments increased by 20–25% when studying the physics course. The project activities contributed to the development of systems thinking and an innovative approach to solving the production problems, which is especially important when mastering physics. A conclusion is made about the need to introduce an activity-based approach to train competitive specialists, adapted to the modern challenges of the agro-industrial complex, which, in turn, contributes to the formation of an innovative educational environment, focused on the development of

professional competencies, engineering creativity and practical training of the students when studying the physics course.

Keywords — *activity-based approach, engineers, innovations, practice-oriented training, professional training, Introduction*

I. INTRODUCTION

The rapid development of the agro-industrial sector gives rise to a demand for training specialists of a fundamentally new format, who possess not only a solid theoretical base but who are also able to solve promptly applied problems, to master contemporary technologies and implement innovations in practice, which is especially important when studying a course of physics. The traditional models of education often do not allow the future engineers to acquire to the full extent the required practical skills and abilities, which becomes noticeable when mastering physical disciplines.

In this regard there is a need to introduce a multifaceted activity-based approach that gives the students an opportunity to design independently professional assignments, seek out non-standard solutions and improve critical thinking, especially when studying a course of physics. However, the implementation of such an approach is often faced with the problem of the lack of a systemic pedagogical support that would combine the optimal selection of methods, effective assessment tools and full-fledged mentoring.

Online ISSN 2256-070X

<https://doi.org/10.17770/etr2025vol3.8552>

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The traditional teaching practices do not always provide sufficient orientation to the development of activity-based, project and research skills in the future engineers, which becomes especially evident when studying the course of physics. The lack of a comprehensive system of pedagogical support for the introduction of an activity-based approach into the educational process hinders the development in the students of the necessary competencies, flexibility of thinking and the ability to make independent decisions in difficult production conditions, which negatively affects the study of physics.

Over the past decade's issues of implementing an activity-based approach in training specialists have retained the status of one of the main topics of scientific discussions, invariably arousing interest of the researchers and teachers. The research into the problem of the activity-based approach among the specialists of various profiles was revealed in the scientific works of [1] - [4] and others.

The works [5] – [7] present the results of a study on the introduction of the active learning methods (team projects, debates, presentations) in the training of the future agricultural engineers. The authors emphasize the importance of a systematic methodological support and mentoring of the teachers, which ensures efficient assimilation of theory and simultaneous acquisition of practical skills, including when writing scientific papers [8].

In the investigation there are treated interdisciplinary approaches to training engineers, including the integration of agricultural, engineering, economic and environmental disciplines. The researchers analyse the results of the embedded courses and seminars that helped the students to think systematically and solve multidisciplinary problems [9].

Application of digital simulations and virtual models in the educational process is described in the works [10] – [13]. Interactive tools have been shown to enhance the understanding of complex technological operations and allow the students to experiment safely with the parameters of the production system. It is shown how the interactive tools enhance understanding of complex technological processes and allow the students to experiment safely with the parameters of the production system.

Although scientific and methodological investigations analyse carefully the problem to be considered, they often lack practical recommendations and particular solutions for its efficient elimination when studying a course of physics. The substantiation and development of a system of pedagogical support for the implementation of an activity-based approach in the training of the future engineers, aimed at integrating fundamental knowledge with practical skills, the development of professional thinking, critical analysis and the ability to make decisions in real production conditions when studying the physics course became the main goal of our study. Modern approaches and methods for solving scientific and practical problems, considered by the researchers in various fields come to the help here [14], [15].

This article is aimed at theoretical substantiation and presentation of a model of the system of pedagogical assistance that promotes comprehensive implementation of an activity-based approach to the training of engineers who are studying a course of physics, as well as at presenting the results of its experimental testing in a real educational process.

Thus the search and scientific substantiation of an efficient mechanisms for the pedagogical support of this process is an urgent task, the solution of which will increase the competitiveness of the graduates in the labor market and ensure their contribution to an innovative development of the agro-industrial complex when studying the course of physics.

II. MATERIALS AND METHODS

The activity-based approach expresses an idea that the main condition for successful learning is the involvement of the students in active and conscious activities that are close to real professional practice. In the context of training engineers, the students' activities should include analytical, design and technological components that reflect the key aspects of their future specialty. The practice-oriented way of training ensures the formation of professional competencies, necessary for the development, operation and maintenance of agricultural machinery, the implementation of digital solutions in the agro-industrial complex and rational use of natural resources.

To achieve this complex result, educational programs, based on the activity-based approach are needed: laboratory and practical classes, the research and project works, as well as industrial practices. However, the key factor in the efficiency of such programs is a systematic support of the teachers who provide methodological, advisory and organizational assistance to the students at all stages of their studies. To implement the activity-based approach, we used the following implementation principles:

A. Activity and independence.

This principle involves a transition from passive perception of information by the students to their conscious and active participation in the educational process. It is implemented through the creation of conditions in which the students do not simply receive ready-made knowledge but are actively involved in the development and implementation of their own projects; they formulate hypotheses, and look for ways how to solve practical problems. The teacher here plays the role of a consultant and mentor, helping the students develop self-study skills and determine their own learning path. The principles of activity and independence in teaching physics to the engineers are aimed at involving the students into the learning process, developing their ability to solve problems independently and apply the knowledge in practice. Here are some examples of their use:

1. Creating a model of a solar panel for a farm (the students independently study the materials about the physics of solar energy; they calculate the coefficient of

efficiency of the panel and select appropriate parameters for a particular region).

2. Development of a setup for measuring the soil moisture (the students independently design the experiment, select sensors, determine the influence of the physical factors, such as temperature and pressure).

3. Modelling the operation of the irrigation system (the students solve problems about calculation of pressure in the system, required for uniform distribution of water across the field; they must select independently the parameters of the pump, take into account the lift height and losses in the pipes).

4. Reducing the energy costs for cooling the grain storage facilities (the students study the heat transfer processes, perform calculations for the wall insulation, and select optimal materials and cooling methods).

This approach helps the engineering students understand better physics and its application in their professional activities.

As a result of such an educational project, the future engineers learn to apply physical and engineering laws to solve very real problems in the agricultural sector. Active involvement and independence at every stage – from calculations and design to the analysis of the obtained data – forms a deep understanding of the theory and increases motivation for further development of more complex technological solutions.

B. Practical orientation approach.

For this purpose, examples and cases, reflecting the modern requirements of the market of an agro-industrial complex are introduced into the training program, whether it be research into new agricultural technologies, analysis of digital solutions in the agro-industrial complex, or the development and testing prototypes of technical devices. A practice-oriented approach helps the students to understand the value of their knowledge and skills, it helps them to establish a link between theory and practice, and also develops the ability to make decisions in conditions that are as close as possible to real production situations (Table 1):

TABLE 1. PRACTICE-ORIENTED APPROACH IN STUDYING THE COURSE OF PHYSICS

The task	Practical application
Studying of mechanical properties of materials, used in agricultural machinery.	Conducting the laboratory work to determine the modulus of elasticity, tensile strength and plasticity. This can be linked to the analysis of the choice of materials for ploughs, seeders or other machines.
Studying of Newton laws and the dynamics of rotational motion.	Calculation of torque and angular velocity of the shaft of a tractor or other agricultural machine, followed by the analysis of their efficiency in real operating conditions.
Studying of the heat transfer and basic laws of thermodynamics.	Modelling the operation of grain dryers or the engine cooling systems. For example, you can perform an experiment to calculate the heat loss and select

	materials for insulating the drying chambers.
Studying of the basics of electromagnetism and the laws of electrical circuits.	Building an electrical circuit for the irrigation systems or greenhouse lighting. You can also study the use of electromagnetic motors in modern agricultural installations.
Studying of the laws of hydrodynamics (for example, the Bernoulli equation).	Analysis of a pump operation in the irrigation systems, calculation of pressure in the pipelines and their capacity.
Study of the principles of operation of optical devices and light radiation.	Studying of the optimal light spectrum for growth of plant in greenhouses and calculation of the required power of lamps.

This approach not only increases the students' interest but also prepares them better for real professional work.

C. Integrativeness.

One of the key features of the training of engineers is the need to combine engineering, agronomic, economic and managerial aspects. The principle of integration implies the development of a systemic vision of the production processes in the students and the ability to use knowledge from different areas as a complex. This can be accomplished through interdisciplinary modules, group projects and research tasks that require the students to draw knowledge from multiple disciplines. Due to this the future specialists are able to interact more efficiently with various participants in the agro-industrial process and offer solutions that take into account the technological, economic and environmental factors. The principle of integration in the teaching of physics to the engineers proposes combination of the knowledge from different disciplines, an interaction between theory and practice, and the application of physical principles in professional activities. This allows the students to see physics as part of a complex system of knowledge and understand better its applied significance. An integrated approach to studying physics for engineers allows for efficient linking of physical processes with other sciences and professional tasks. In integration with biology the students study the heat exchange in the plants, such, as moisture evaporation through the leaves, and they model microclimates in the greenhouses, analysing changes in temperature and humidity depending on the time of the day and external conditions. The inclusion of chemistry helps to understand the corrosion processes of the agricultural equipment, where the students conduct experiments to study the effects of various conditions on the metal corrosion and develop methods to prevent it. Integration with mathematics is manifested through the calculation of the vibration parameters of the agricultural machinery, such as amplitude, frequency and period of oscillations, with the creation of mathematical models for the analysis of their impact on the quality of work. The use of the computer science allows the students to model electromagnetic fields and develop computer models of electrical circuits to automate, for example, irrigation systems, using the software tools, such as MATLAB or COMSOL Integration with engineering design includes tasks on calculating irrigation systems taking into account the hydraulic

resistance, where the students create drawings of such systems using the engineering software, such as AutoCAD. Such an approach develops systemic thinking, strengthens the link between theory and practice, and develops skills for the solution of complex tasks.

The application of the principle of integration in the study of physics allows one to strengthen the link between theory and practice, which makes the learning process more meaningful and useful for the students. This promotes the development of systemic thinking, allowing the students to see the interrelationships between different disciplines and apply the physical laws to the real-world tasks. During the training process skills for complex analysis of professional tasks are developed, which are necessary to solve practical problems in engineering. In addition, demonstrating the applied significance of physics in professional activities increases the students' motivation to study it, making education more interesting and oriented to the future career. In addition, demonstration of applied importance of physics in the professional activities increases the students' motivation to study it, making education more interesting and career-oriented.

D. Continuity.

Pedagogical support and organization of the educational process should be structured in such a way that the students have a constant opportunity to receive the feedback, to correct their actions and reflect on the material covered. In practice this principle is manifested in systematic consultations, regular monitoring of the academic performance with analysis of achievements and mistakes, and involvement in reflective activities (diaries, reports, group discussions). The continuous way of learning promotes conscious acquisition of the new material and the students' ability to maintain professional fitness in the rapidly changing agricultural sector. The principle of continuity in the study of physics for engineers ensures consistent and systematic development of the knowledge and skills, related to their professional activities. The training is structured in such a way that each new stage is based on the previous one: from studying the basics of mechanics and thermodynamics to an in-depth understanding of electromagnetism and hydrodynamics. The constant link between theory and practice is achieved through the laboratory work, project assignments and solution of professional asks, such as the analysis of the irrigation systems, the calculation of thermal processes in greenhouses or the study of the dynamics of agricultural machinery. Interdisciplinary integration with mathematics, chemistry and biology strengthens the understanding of physics as part of the engineering system. As a result, the students gain a holistic understanding of the subject, strengthen their skills in solving complex tasks, and better understand the practical significance of the processes being studied.

III. RESULTS AND DISCUSSION

The experimental testing was accomplished with the aim of testing the efficiency of an introduction of the system of pedagogical support for an activity-based

approach into the educational process of training the future engineers.

The experiment was conducted at the institution of higher education "Podolsk State University" among the students of the specialty 208 "Agroengineering" with a total number of participants of 120 people, divided into experimental and control groups of 60 students each. Approbation of the methods was made on the course of one semester. At the main stage the students in the experimental group completed projects and practical assignments, worked in teams, and regular feedback through questionnaires contributed to a prompt adjustment of the educational process. The results were assessed using a complex approach: the academic performance was analysed, testing, expert assessments and questionnaires were conducted, which made it possible to compare the data of the experimental and the control groups (Table 2).

TABLE 2. RESULTS OF THE EXPERIMENT ON THE IMPLEMENTATION OF THE METHODS OF AN ACTIVITY-BASED APPROACH

Indicator	The experimental group	The control group
Average score of academic performance	Increase from 70 to 84 (increase by 20%)	Insignificant change: from 70 to 72
Indicators of practical skills	Rating – 90 points (growth from 75 to 90, +20%)	Stable level: 75 points
Level of involvement	90% positive feedback, based on the survey results	70% positive reviews
Number of completed projects	13 projects (30% increase, in comparison with 10 basic)	10 projects

The statistical analysis revealed a significant impact of the new methods on the quality of learning: the average score of the experimental group increased by 15–20%, compared to the control group, and the indicators of practical skills improved by an average of 25%. These numerical data have demonstrated the high efficiency of the implementation of the activity-based approach and become the basis for formulating conclusions and recommendations for its further application in the educational practice.

In the research the assessment of the formation of professional competencies was performed in a complex manner. Each of the key indicators – the skills of the project work, the ability to apply theoretical knowledge, the teamwork, critical thinking and independent solution of professional problems – was assessed on a scale from 1 to 10. The students filled out questionnaires where they independently determined their level of proficiency in competencies, and the experts (the teachers and invited employers) gave objective assessments, based on the analysis of practical work, presentations, and the results of completed assignments.

Below is a table in which the results of the assessment of the students' key professional competencies in the experimental and the control groups are compared,

indicating the values for both the self-assessment and the expert's assessment:

TABLE 3. RESULTS OF THE ANALYSIS OF THE FORMATION OF PROFESSIONAL COMPETENCIES

Key competencies	The experimental group		The control group	
	self-assessment	expert assessment	self-assessment	expert assessment
Skills of the project activities	8.3	8.0	7.5	7.2
Ability to apply theoretical knowledge	7.8	7.5	7.0	6.8
Teamwork	8.5	8.3	7.8	7.6
Critical thinking	7.6	7.2	7.0	6.5
Independent solution of professional tasks	8.0	7.8	7.4	7.1

The students of the experimental group showed higher results in all aspects considered: the skills of the project activities, an ability to apply theoretical knowledge, the teamwork, critical thinking and an ability to solve independently professional tasks. For example, in the field of the project activities, self-assessment was 8.3, and the expert assessment was 8.0, which significantly exceeds the indicators of the control group (7.5 and 7.2, respectively). A similar picture is observed for the other competencies, which indicates the positive impact of the applied activity-based approach methods. The difference between the groups' assessments confirms that the integration of practical assignments, the teamwork and the systematic feedback contributes not only to the improvement of the students' perception of their own capabilities but also to the objective growth of professional skills, which generally has a positive effect on the development of the professional competence.

The obtained results became the basis for further improvement of the educational programs in studying the course of physics: the areas, where significant discrepancies were noted, received additional attention, and the successful aspects were integrated into the general teaching methods in studying the physics course. Such a method allowed not only to assess the current level of professional training of the students in physics but also to identify particular recommendations how to improve the quality of education and develop the key professional competencies when studying a course of physics. Such a complex approach allows for a comprehensive assessment of the development of the key competencies using both the quantitative and the qualitative methods of analysis.

As part of the study, the students' satisfaction with the learning process was assessed using a questionnaire. Comparative results of the control and experimental groups for the following indicators: average score; successful completion of practical assignments; the skills of project work; the teamwork and students' satisfaction are presented in Fig. 1.

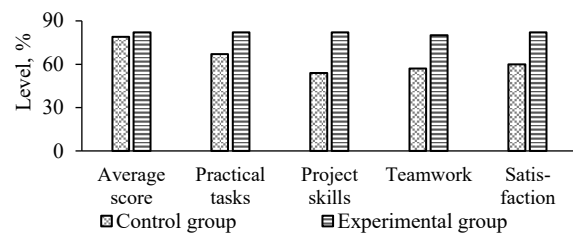


Fig. 1. Comparative results of the control and the experimental groups.

The experimental group showed significant improvement in all parameters, confirming the efficiency of the activity-based approach in the educational process.

It is recommended to expand the use of the activity-based approach to the other academic disciplines, including natural sciences and humanities, which will allow for the development of interdisciplinary thinking and the application of knowledge in practice. Particular attention should be paid to the project activities and the teamwork, which contribute not only to the deepening of professional knowledge but also to the development of soft skills, such as communication, leadership and time management. It is also important to increase the frequency and quality of feedback, providing students with detailed guidance and support to increase their motivation and involvement.

IV. CONCLUSIONS

Experimental testing confirmed that the system of the pedagogical support for the activity-based approach significantly improves the educational results and the students' satisfaction. This approach allows not only to improve the academic performance but also to develop the key professional competencies, necessary for the future engineers to successfully work in the agro-industrial complex. A comparative analysis of the indicators of the experimental and the control groups revealed that the students who studied, using the innovative methodology, demonstrated significant growth in all the key indicators: the average academic performance score increased by 15–20%, and practical skills by 20–25%, which was confirmed by both self-assessment and the expert assessment (the teachers and invited employers). An integrated approach to the assessment, including testing, questionnaires and expert observation, made it possible to objectively identify the positive impact of the activity-based methods on the development of the project skills, application of theoretical knowledge, the teamwork, critical thinking and independent solution of professional tasks.

However, the key feature of our study is not only a quantitative assessment of the efficiency of the project-based learning but also a deep analysis of its impact on the development of the engineering creativity and the students' ability to solve independently real tasks of production. Unlike most investigations where the emphasis is on the traditional forms of training or the use of individual elements of practice-oriented methods [1] – [4] [8] our work examines the comprehensive integration of the project activities, the engineering modelling and interaction with real manufacturing enterprises. This not only

improves the students' academic performance but also develops the key skills that are in demand in the agricultural sector.

One of the unique aspects of our research is the inclusion of multi-component engineering problems into the educational process, requiring from the students not only theoretical training but also active application of the knowledge in the conditions of uncertainty. Such an approach helps develop in the future engineers systemic thinking, innovative approaches and the teamwork skills. This aspect is rarely considered in the domestic and foreign investigations where, as a rule, the emphasis is on the use of individual digital tools without a comprehensive assessment of their impact on the students' professional training [9].

Thus our research not only confirms the efficiency of the activity-based approach but also demonstrates new promising methods for training engineers that have not received sufficient treatment in other works. The developed methodology combines elements of the project-based learning, the engineering modelling, flexible educational trajectories and active interaction with the real production processes, which makes it a significant step forward in the field of engineering education. The prospects for further research include the development of digital tools for the individualization of learning, the development of new criteria for assessment of engineering competencies, and the expansion of interaction between educational institutions and agro-industrial enterprises.

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Readjusting for Digital Transformation: A Primary Mathematics Framework

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Abstract— The increasing digitalization of education necessitates reconsidering primary mathematics instruction. This study explores the integration of blended learning in Latvian primary mathematics classrooms, addressing the evolving roles of students, teachers, and curricula in the digital age. Using a mixed-methods approach, we analyzed 60 mathematics lessons from 2022 to 2024 to assess student learning opportunities for blended learning. The findings indicate that while digital technologies are present, their pedagogical use remains limited. No observed lessons fully implemented blended learning, though some teaching profiles demonstrated elements of self-regulated and deep learning. Based on these findings and a review of the literature, we propose a conceptual framework for content and process integration for mathematics teaching in the digital age. The framework emphasizes the significant role of the digital dimension complementing the traditional didactic triangle of learner, teacher, and curriculum. This highlights and influences how we view self-regulation, communication, motivation, and process-content integration. Our study highlights the need for curricular adjustments and targeted professional development to better align teaching practices with the realities of digital transformation, ensuring students develop the necessary competencies for the future.

Keywords— *Blended learning, digital transformation, mathematics education, primary education.*

I. INTRODUCTION

Workplace and education landscapes are changing due to digitalization and the development of technologies. The later years of formal education cannot be imagined without including blended learning to some extent [1]. This asks for a set of relevant skills and not just digital competencies [2]. Change is not just in the form of learning, the actual content needs to be adjusted for the changing skillset needed to ensure student success. When thinking about teaching in the present day, it should not be forgotten that childhood and adolescence have changed too - constantly surrounded

by screens and ongoing entertainment. Student experiences before and during formal education are vastly different than those of previous generations and this should be taken into consideration when thinking about their teaching and learning. The change does not stop here. The role of the teacher is rapidly changing as well due to the development of generative artificial intelligence and individual virtual tutors being accessible to students. All of the above-mentioned factors are highly influenced by the circumstances of the country in which the person lives and other contextual (e.g., socioeconomic, cultural) aspects.

"In recent years, the internationalisation and globalization of the economy, universality of technological development and related needs for new skills and knowledge play the role of strong motivations for curriculum reforms"[3]. Blended learning, particularly through flipped learning, rethinks the organization of the learning landscape by moving direct instruction to individual learning spaces and transforming group spaces into interactive environments. This approach, supported by digital technologies, enhances student engagement, interaction, and understanding, though it can also present challenges due to increased workload and unfamiliarity with the method [4].

The design of an effective mathematics curriculum is influenced by key educational theories that focus on how students learn, process, and apply mathematical concepts. These theories guide the selection of content, teaching strategies, and assessment practices to promote deep understanding, critical thinking, and problem-solving skills.

In this research paper, we aim to explore what these changes mean for primary mathematics education in Latvia and conceptualize the involved aspects within a theoretical framework.

Online ISSN 2256-070X

<https://doi.org/10.17770/etr2025vol3.8554>

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RQ1 What opportunities do students have for blended learning in primary mathematics in Latvia?

RQ2 How to develop a primary mathematics framework in the midst of digital transformation?

A. Digital transformation and blended learning in primary mathematics

Students, who attend school at present day are “digital natives” who have transferred many aspects of their lives to digital technologies and have intuitive navigation skills on many digital devices and applications. Their skills and experiences are vastly different from previous generations of students [5]. Teachers and students have a large gap in experiences and values and it affects teacher understanding of their students and their needs. Students have a different starting point when entering mathematics classrooms. For example, the experience of physical money is replaced by credit cards, analogue watches with digital watches, playing with blocks and roleplay games with video games and videos (sometimes educational).

Teachers must therefore balance traditional mathematical skills with newer competencies that emphasize real-world applications and digital fluency. As digital tools become more accessible, curricula are shifting from repetitive manual calculations to tasks that engage students in mathematical reasoning and problem-solving using technology [6].

We agree with the idea that there is no didactic triangle anymore, but rather a didactic pyramid (Dasari et al.2023), where there are four vertices – student, teacher, curriculum and digital technologies. The digital technologies are not solely a different platform for learning or another way to represent the learning content, but they provide possibilities to gather precise data for teachers, receive immediate individualized feedback for students, boost engagement and we cannot forget the above-mentioned experiences and skills of digital natives. Digitally literate students can access, create, and communicate information, adapt to changing technologies, and use information and communications technologies ethically and responsibly. This competency should be strongly emphasized in curricula [6].

With digital technologies entering the classroom so does blended learning and that can be beneficial for student outcomes since “the use of blended learning has a major effect on students' mathematical abilities when compared to traditional learning”[7], if the teacher has appropriate knowledge, skills and tools.

B. Curriculum changes

Designing a mathematics curriculum in the digital age requires a careful balance of content and process. Our content and process integration framework was designed to emphasise the changes necessary due to digital transformation and based on the new curriculum in Latvia in order to help teachers adapt and implement the changes.

When looking at other countries' successful implementation of needed changes, the curriculum must emphasize the importance of problem-solving, reasoning,

and real-world applications. It must ensure that students not only learn mathematical procedures but also understand their practical relevance. The Australian framework's [8] organization around key content and proficiency strands ensures a holistic and practical understanding of mathematics, integrating various domains such as numbers and algebra, measurement and geometry, and statistics and probability. By focusing on understanding, fluency, problem-solving, and reasoning, the curriculum supports the development of comprehensive mathematical skills. Adopting a spiral approach, as seen in the Singaporean curriculum [9], is crucial for revisiting and deepening the understanding of key concepts over time. The Concrete-Pictorial-Abstract approach further enhances this by helping students develop a strong conceptual understanding before moving on to abstract procedures. Promoting inquiry-based learning is another vital aspect of an effective mathematics curriculum. Encouraging exploration, questioning, and problem-solving fosters critical thinking and deeper understanding. This student-centred approach aligns with constructivist principles, where learners actively engage with mathematical problems and discover solutions through guided inquiry [10]. Such a comprehensive approach ensures that students develop deep mathematical understanding, critical thinking skills, and the ability to apply mathematics in a variety of contexts, preparing them for success in the digital age.

The Programme for International Student Assessment (PISA) stresses the role of mathematical literacy as a central goal in school mathematics education because it improves the life opportunities for students, and justifies why mathematics is essential to describe, explain and predict the world [11]. The curriculum content and methods for introducing revised curricula cannot be directly transferred from one country to another. They can vary based on cultural and historical backgrounds, traditions, as well as political decision-making processes [2]. It should be noted that digital competency frameworks are general and not subject-specific, but they are also likely to influence subject-matter content [4].

An Organisation for Economic Co-operation and Development (OECD) study [6] highlights gaps between curriculum content and real-world applications, particularly in mathematics. The slow adaptation of curricula from routine calculations to problem-solving and real-world applications, combined with traditional rote learning methods, may not adequately prepare students for higher-order skills, leading to declining performance.

C. Key learning processes in the digital age and blended learning

There is a shift in mathematics education from individual knowledge acquisition to collaborative and public practices that co-construct knowledge. Digital resources enhance this shift by enabling communication and collaboration over long distances and asynchronously, placing these elements at the center of modern pedagogies [4]. For students to thrive in a blended learning environment, their teachers must think about student self-regulated learning, communication and motivation. These

key aspects besides digital fluency are becoming more important for learning in the digital age [12].

1) Self-regulated learning

Skills related to self-directed learning or self-regulated learning are known to be the skills that each successful learner needs to obtain [13]. These skills are necessary not only for continuous learning needed in many workplace environments but for the future of student's academic learning. Inescapably it will be in some way blended learning, where parts of the learning happen in a digital environment and at least somewhat independently. The learner must regulate his behaviour and motivation to start a task, keep his attention on it and reflect on the process and results. Research shows [14] that for students to be able to thrive in blended learning environments they need self-regulated skills. These skills help not only for blended learning but are beneficial for overall mathematics performance for primary students [14]. We will be using the term self-regulated learning for the primary school context, since self-directed learning is associated with the learner's full responsibility for all of the learning process, determining goals and all the steps towards it [15]. Still, self-regulated learning is on a reduced scale, where the learner's responsibility is around particular tasks and projects [15]. We consider the term self-regulated more appropriate since in primary school the learning goals are predetermined by the curriculum, program and teacher and the tasks and learning process are designed by a teacher (even if students have opportunities to express opinions when defining the goals or choosing tasks, they do not have a say in what they have to learn when finishing each step in their formal education) and the responsibility for his learning experience lies on the teacher [16]. Self-regulated skills are related to (meta)cognitive strategy use, motivational, emotional and behavioural regulation of oneself [17]. These skills are used throughout all the phases of self-regulated learning [18] – the forethought phase, the performance phase and the self-reflection phase.

Self-regulated learning and student agency have also yielded changes in the pedagogies to make use of the affordances of digital resources to foster these new educational ideals.

a) Metacognition

We would like to stress the importance of metacognitive awareness and skills when thinking about mathematics education and blended learning. Metacognition involves the conscious awareness and oversight of one's thought processes, including recognizing how and why you think or act in certain ways, as well as making deliberate choices to modify or adjust them [19]. This reflective practice helps students develop more effective learning strategies, connect mathematical concepts, and improve their overall performance in mathematics [20]. This can be taught by explicitly teaching cognitive and metacognitive strategies, modelling the use of metacognitive skills (e.g., "thinking aloud") and investigating the thought processes of others [21], [22]. Integrating metacognitive strategies into blended learning

models significantly improves students' ability to understand mathematical concepts and manage their learning processes [23].

2) Communication

Communication refers to the ability to use mathematical language to express mathematical ideas and arguments precisely, concisely and logically; analyze their peer's mathematical ideas and strategies [24]. It helps students develop their understanding of mathematics and enhance their mathematical reasoning [25]. The skill evolves if there is an engaging, inclusive classroom discussion leading to deep thinking and diverse and purposeful representations and explicit transitions are used [24].

a) Classroom discourse

The typical approach to questioning in elementary mathematics classrooms in Latvia often involves only recall, where teachers expect a single correct answer without delving into students' reasoning [26]. Even when students are asked to explain their solutions, teachers usually anticipate a single correct method. This approach confirms individual students' knowledge but does not facilitate deep learning.

During the learning or comprehension phase of a lesson discussions should be structured to allow students to learn, explain, reason, and deepen their understanding. Productive classroom discussions involve various conversational tools or talk moves that encourage students to articulate their ideas, listen to others, recognize different approaches, and evaluate them critically. These strategies include [27]:

Revoicing: the teacher repeats or paraphrases the student's response and asks for confirmation or clarification. This ensures the understanding of the student's idea and makes it accessible to others.

Repeating: asking students to restate another's reasoning in their own words. This helps reinforce understanding and validates peer contributions.

Reasoning: using student ideas to continue the discussion, by asking students to reason about other reasoning. Asking students to evaluate or justify ideas.

Adding on: Prompting students to extend their own or others' thoughts.

Wait time ("Thinking time"): Allowing sufficient time for students to process questions and formulate responses is critical. Research [28] shows that teachers typically wait only about one second for a response. However, when wait time exceeds three seconds, student engagement, response quality, and cognitive depth improve significantly.

Pair or small group discussions (turn and talk): Ask students to exchange ideas with a partner or small group before sharing with the whole class. This move gives students the opportunity to formulate their ideas, ascertain that they are thinking in the right direction or arrive at a

solution together. It gives each student the opportunity to use mathematical language.

Additionally, it is important for teachers to evaluate the questions they pose to make sure they are not solely relying on those that require only basic cognitive skills. They should avoid prematurely giving students answers, as this can be demotivating.

b) Representations

Mathematical understanding deepens when students engage with multiple representations of concepts, including arithmetic operations. Using various representations expands comprehension, helping students determine when and how to apply mathematical operations and interpret results [29]. Effective mathematics instruction connects representations to reinforce conceptual understanding and problem-solving skills [30].

A mathematical representation is a mental or tangible construct that describes a concept and its relationships. Experiencing a concept across different contexts strengthens understanding [31]. Representations serve several roles in learning [30]: establishing a foundation for mathematical understanding, clarifying mathematical contexts, identifying relationships between concepts, and enabling communication of understanding and reasoning.

Representations illustrate mathematical ideas. There are five representations (static pictures, written symbols, spoken language, real scripts, and manipulative models) and their interconnections [32], or six, if we count digital representations as a separate category since it provides the possibility of “moving pictures” [33]. Crucially, students must develop the ability to transition between representations, selecting the most effective form for problem-solving. Teachers in Latvia struggle to incorporate all of the representation in their teaching [34].

3) Motivation

Teacher beliefs about their students’ motivation and what affects it (e.g. whether the teacher can influence it or it is all up to the student) are shaped by a variety of factors [35], [36]. First, their knowledge about what motivates students (from teacher education) and learning (e.g. beliefs that student achievement is solely or mostly dependent on an innate ability[37]). Teachers’ philosophical views on motivation and mathematics learning (behaviourism vs autonomy, supportive teaching, direct instructions and memorization vs learning through problem-solving) are another factor. In addition, personal experiences related to mathematics learning and motivation influence teacher beliefs. Teacher beliefs have been shown to affect student outcomes [38].

For exploring motivation in the classroom and the teacher’s role in it, we use self-regulation theory because of its broad research and straightforwardness.

II. MATERIALS AND METHODS

A mixed research design was used for this research.

The study sample consists of 60 primary mathematics lessons (grades 1-6). The lessons were observed, transcribed and rated across multiple criteria on a scale from 0 to 4 between the years 2022 and 2024 by experienced and specially trained primary STEM teaching experts. No information about teacher and student demographic characteristics is available to the authors. For the present research, the authors obtained the lesson transcripts and ratings from a database. A rubric “Teaching and Learning Assessment to Support the Teaching of Student 21st-Century Skills”[39] was used to determine teaching performance levels by comparing theoretically described preferable practices and the observed ones.

TABLE I. AN EXAMPLE OF A CRITERION “CLASSROOM DISCOURSE” WITH LEVEL DESCRIPTIONS

Level	Description
0 (Not observed)	The teacher introduces information and explains concepts. If questions are asked, they are closed. Students mainly listen, observe, and take notes.
1 (Beginner)	The teacher's monologue dominates. However, some elements of discourse can be observed – the teacher asks questions but expects specific answers. Questions are only used for checking knowledge. If students fail to provide prompt expected answers, the teacher answers them him/herself. Students answer particular questions and/or ask very few questions.
2 (Developing)	Alongside explaining and asking questions, the teacher creates a situation where students have to pose questions about the content of the lesson. If needed, the teacher instructs students on how to form questions and how to engage in conversation. The teacher tries to provide enough time for students to think over their answers; however, the time is often insufficient. Students feel free to ask questions and engage in conversation.
3 (Proficient)	The teacher asks diverse questions, including those where there is no single right answer, and asks for students’ thoughts and reasoning. The teacher uses questioning and different student responses to extend the discourse either frontally or in groups (pairs). If needed, the teacher rephrases student questions. The teacher gives students enough time to think during the discussion. Students have a clear understanding of the procedure of classroom discourse – how to ask and how to answer. Students ask diverse questions.
4 (Expert)	With appropriate questions, the teacher creates situations to engage students and deepen their thinking. Students ask diverse questions, initiate and lead discussions, and are active and fully engaged in thinking.

The rubric consists of 17 criteria, in each criterion, teaching practices are described in 5 levels. The teaching practice is rated at level 0 if the respective criterion is not observed; and level 4 if the teaching practice represents exceptional practice. An example of the criterion “classroom discourse” with level descriptions is provided in Table 1.

The lesson rating was done by the same experts, who observed and transcribed the lessons; a substantial

interrater agreement had been achieved before the experts rated the lessons individually.

For determining typical student opportunities (and differences) for blended learning in mathematics classrooms a profiling approach was used. This approach identifies distinct groups or profiles of teaching that exhibit similar patterns of strengths and areas for improvement [40]. The profiles are derived from classroom observational data and help in summarizing and interpreting the teaching quality and professional development needs of teachers. A previously developed decision tree with respective categories and criteria (Table 2) for the determination of primary STEM teaching profiles was used [41].

TABLE II. CATEGORIES THAT CONCEPTUALIZE BLENDED LEARNING IN STEM AND THEIR RESPECTIVE CRITERIA

Categories	Criteria
1. Opportunities to learn with digital technologies	1.1. Meaningful use of digital technologies by students
2. Student self-regulated learning opportunities	2.1. Clear learning objectives
	2.2. Feedback to students
	2.3. Opportunities for metacognition
	2.4. Differentiation and support for learning
3. Student deep learning opportunities	3.1. Curriculum representation
	3.2. Tasks for deep learning
	3.3. Classroom discourse

III. RESULTS AND DISCUSSION

A. RQ1

There were no lessons observed where blended learning was fully implemented or the kind of teaching where all the skills necessary for blended were used. In some 12% of the sample lessons digital technologies were used, but in none of the lessons were they used for learning. Nevertheless, the profiles show how the student learning opportunities prepare them for later blended or independent learning (see Table 3).

There were 4 distinct teaching profiles. Teaching that corresponds with **profile 1** provides students with some self-regulated and deep learning opportunities. **Profile 2** teaching provides students with some self-regulated but very limited deep learning opportunities. **Profile 3** teaching provides students with some deep learning but very limited self-regulated learning opportunities. **Profile 4** teaching provides students with very limited self-regulated learning and deep learning opportunities.

TABLE III. AVERAGE PERFORMANCE LEVELS ACROSS THE SELECTED CATEGORIES AND CRITERIA CORRESPONDING TO THE FOUR OBSERVED PRIMARY MATHEMATICS TEACHING PROFILES (N=60)

Profile	No. of lessons	Cat. 1	Cat. 2				Cat.3		
		1.1.	2.1.	2.2.	2.3.	2.4.	3.1.	3.2.	3.3.
1	19 32%	0,2	2,0	1,8	0,7	0,9	1,8	1,3	1,5
2	8 13%	0,1	1,4	1,4	0,4	0,5	0,8	0,5	0,8
3	6 10%	0,0	0,7	0,8	0,3	0,0	1,3	1,3	1,2

4	27 45%	0,1	0,6	0,9	0,2	0,3	0,7	0,6	0,7
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When looking at the categories (Fig.1), students had more opportunities for deep learning than self-regulation. Within the categories, students often received clear, specific, measurable and achievable learning objectives and feedback concerning the planned learning objective or the learning process, but very rarely received different tasks or other ways to learn according to their abilities or used metacognitive strategies (Cat.2.). Within the 3rd category – all criteria were similarly observed overall, with performance a little higher in content representation and work with student perception. Learning tasks were mostly reproductive and required low cognitive skills, and discourse was mostly one-way - where the teacher does a lot of talking and asks questions primarily for recall.

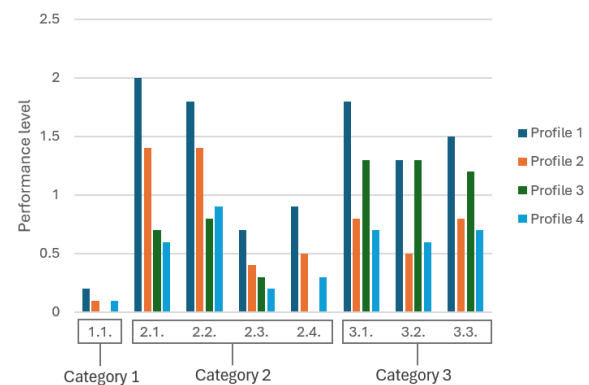


Fig. 1. Bar chart of the average performance for the teaching profiles in each criterion.

B. RQ2

Based on literature analysis and taking into consideration the given context a framework for content and process integration for mathematics teaching in the digital age was created.

As previously mentioned, we consider the students' experience in the digital world as a crucial element which influences the primary mathematics curriculum. Additionally, we assert that the curriculum should set objectives for students who are well-versed in the digital world, regularly accessing information, communicating, and learning through digital technologies. Thus, the framework includes (see Fig. 2) digital technologies as a separate dimension that intertwines with other framework elements and encompasses digital competence and the ability to learn via digital technologies. The introduction of digital resources does not only affect the mathematics and related learning goals but also influences students' interaction with mathematics. Besides digital technologies, other dimensions of learning consist of self-regulation, communication and motivation.

The framework also includes five content strands/categories: numbers, measurement, geometry and spatial thinking, data and uncertainty and relationships. The Framework defines content knowledge as the

understanding of mathematical concepts, procedures, facts, and tools necessary to describe, explain, and predict phenomena, ensuring that students can apply mathematics in various real-world contexts. Thus, the four mathematical proficiency strands are defined: conceptual understanding, procedural understanding and fluency, mathematical reasoning, problem-solving and mathematical modelling. Students should have opportunities to apply their

mathematical problem-solving and reasoning skills to a variety of challenges. Through mathematical modelling, they learn to navigate ambiguity, make connections, select and apply appropriate mathematics concepts and skills, identify assumptions, reflect on the solutions to real-world problems, and make informed decisions.

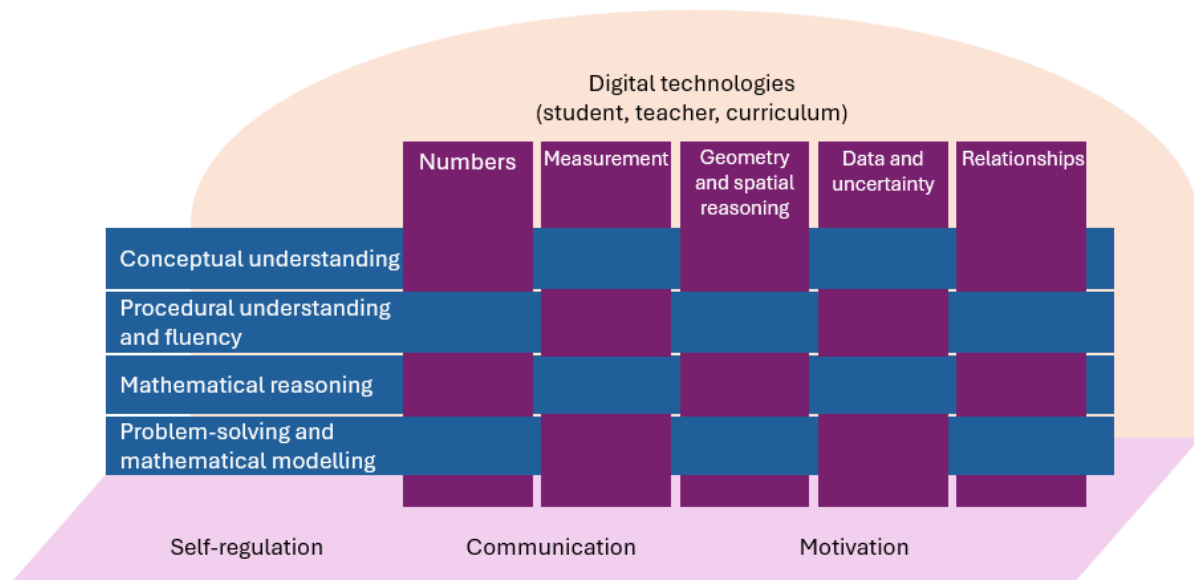


Fig. 2. Content and process integration framework for mathematics teaching in the digital age.

The study, similar to Rezat and Geiger, suggests that while digital resources have the potential to make the sequencing of mathematical content more flexible and adaptable to individual learners, changes to school curricula and school practices have been mostly superficial so far. Providing primary school students with the appropriate tools and language may lead to more personalized learning environments in the future [4].

There are several issues concerning digital transformation that we did not look into in this paper, but that require discussion. While the virtual representation of mathematical objects using the advantages of digital technologies allows for operations with these objects that would not be possible in real life, the question of how students' operations with virtual instead of physical objects influence their learning of mathematics is unresolved. This requires further research since constructivist learning theories have always argued that conceptual development in mathematics is grounded in sensorimotor experiences in the real world and a result of ongoing abstraction [4]. The impact of artificial intelligence systems will significantly accelerate changes in education, as their increasing availability suggests that such transformations are imminent. While digital texts and blended learning offer benefits like easy updating and accessibility, their impact on teachers and learners in curriculum reform is less understood. These resources have the potential to support curriculum communication and adaptation, but their

effectiveness in pedagogical discourse remains complex and context-dependent [42].

Further research should continue on how continuously monitoring students' progress using technology teachers can identify areas where students are struggling and provide targeted interventions to address misconceptions or gaps in knowledge. Effective assessment practices are essential for both measuring student progress and refining the curriculum to better meet the diverse needs of learners.

IV. CONCLUSIONS

This study highlights the limited yet emerging integration of blended learning in Latvian primary mathematics classrooms. While digital technologies are present, their pedagogical use remains underdeveloped, with no fully implemented blended learning lessons observed. Our findings reveal that teaching practices fall into distinct profiles, demonstrating differences in providing self-regulated and deep learning opportunities that are crucial for learning in the digital environment. There is a predominant reliance on teacher-centred discourse and low-cognitive-demand tasks.

To bridge this gap, we propose a content and process integration framework that recognizes the digital dimension as an essential component of mathematics education today. By accepting the expansion of the traditional didactic triangle into a didactic pyramid (including digital technologies alongside the learner,

teacher, and curriculum) we emphasize the necessity of aligning teaching practices with student experiences. The framework underscores the importance of digital literacy, self-regulation, communication, and motivation, ensuring that students develop the competencies required for a technology-driven learning landscape.

Ultimately, for blended learning to become a meaningful component of primary mathematics education, systemic curricular adjustments and targeted professional development initiatives are essential.

ACKNOWLEDGEMENTS

Project “Innovative solutions for blended learning implementation: teaching and learning process in the digital transformation context” VPP-LETONIKA-2021/1-0010.

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WebQuests as a Tool for Developing the Professional Communication Skills of Future Software Engineers in an Inclusive Educational Environment

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Abstract- Modern European countries are actively developing an effective ecosystem of support and professional integration of people with disabilities. In particular, employers receive tax benefits and state incentives for employing specialists with disabilities. In this context, inclusive educational institutions and traditional universities must provide high-quality training for all students to compete in the labour market successfully. Developing soft skills in future engineers, particularly software engineers, is essential. Recent surveys among employers have confirmed their interest in specialists with developed soft skills, including effective communication in at least one, preferably two, foreign languages. One of the effective methods of teaching a foreign language for a professional purpose is using WebQuests. Our study analysed their impact on the educational process with the third-year bachelor students majoring in “Computer Sciences” in an inclusive environment. The research methodology combined quantitative (surveys using the Likert scale) and qualitative (teacher comments) approaches, which allowed us to obtain

a comprehensive assessment of the effectiveness of web quests. A thematic Web quest, “Creating IT startup,” was developed, implemented and adapted for students with special needs (subtitled videos, audio versions of materials, accessible interface). The study results showed that students remembered professional vocabulary better and communicated more effectively in a foreign language in a professional environment. Teachers noted increased students’ involvement in ESP learning and their activity during classes. Respondents confirmed that WebQuests contributed to developing self-study skills essential for training future software engineers. The results proved the feasibility of using WebQuests to teach ESP, especially in inclusive education.

Keywords- *ESP, IT startup, professional communication skills, software engineers, WebQuests*

Online ISSN 2256-070X

<https://doi.org/10.17770/etr2025vol3.8555>

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I. INTRODUCTION

The modern global labour market places high demands on future engineers, who must possess both technical knowledge and developed soft skills. Higher education institutions should prepare specialists with an academic base and technical competencies who can communicate effectively, work in a team, adapt to changes, and think critically.

According to the Vanderlik study "Hard Facts About Soft Skills", in which more than 260 employers participated, 93.1% preferred candidates with developed soft skills. At the same time, 215 respondents noted that they use interviews as the primary method of assessing soft skills, which once again confirms the importance of the ability to communicate effectively. Without the proper level of communication skills, even a high level of technical training does not guarantee success in the labour market.

Institution of Higher Education Kamianets-Podilskyi State Institute is a rehabilitation institution for students with disabilities and other low-mobility groups. The university provides barrier-free access to classrooms and specialized computer laboratories and implements modern technologies for high-quality training of IT engineers.

One of the practical tools for developing professional communication skills in future software engineers is WebQuests. Their use in practical ESP classes contributes to students' ability to work with Internet resources, analyze technical documentation, express their thoughts professionally, and interact with international teams.

Introducing WebQuests into the educational process can be crucial in preparing competitive IT specialists who can work effectively in modern conditions. The present research aims to identify the attitudes of students and teachers regarding the effectiveness of implementing this technology in ESP teaching to future software engineers in an inclusive learning environment.

II. MATERIALS AND METHODS

To search and analyze literary sources related to our research topic, we used the AI platform to analyze scientific publications, such as Semantic Scholar. The platform found 5,010 results for the keywords "Webquest", "ESP" and "Higher Education". After refining the search parameters and adding a technical focus, the number of sources found decreased to 900. Articles that did not correspond to the subject of study, as well as works by authors of the aggressor state following the draft law of the Verkhovna Rada of Ukraine, were excluded. The analysis showed that all researchers recognize Dodge and March as the founders and developers of WebQuests [1] – [4]. They define it as a research-based, reference-oriented activity, which results in students searching for information using Internet resources and video conferences. Many current studies are experimental, with respondents ranging from 30 to 398. The vast majority of studies use surveys and pre- and post-experimental tests.

Since limiting the search to technical majors would narrow our analysis, the literature review includes studies with students from various faculties and majors: mass communications, foreign languages and translation, postgraduate education, architecture, construction, applied arts, economics, and pedagogy. Scientists have studied the impact of WebQuest technologies on various foreign language competencies of higher education students.

In particular, research results have shown a positive impact of this technology on the development of:

- oral communication [5],
- grammatical skills [6],
- academic writing [7],
- reading skills [8],
- digital competencies [9],
- lexical skills [10],
- listening [11].

Several articles analyzed teachers' attitudes towards using web quests in teaching and the features of implementing web technologies in differentiated ESP teaching of future IT specialists [12] and autonomous reading learning [13]. Web technologies contribute to implementing a person-centred approach, individualization and differentiation of learning [14].

Some researchers have suggested making the structure of WebQuest more flexible, for example, not separating the "Process" and "Resources" sections, as well as balancing the level of student autonomy with teacher control [15].

An extended search for additional keywords, such as "inclusive environment" and "universal learning design", revealed limited publications. One of the few sources analyzing the use of the web quest in inclusive education is the work of Kelly [16], which describes the practical aspects of its application in the education of children with special needs.

Thus, the literature review confirms the effectiveness of WebQuest technologies in teaching ESP, particularly in technical education. However, further research is needed to examine their impact on specialized aspects of the learning process in more detail, especially in the inclusive learning environment.

By combining quantitative (survey) and qualitative (teacher comments) research methods, it is possible to comprehensively assess the effectiveness of using Web Quests in teaching English for professional purposes (ESP) to IT students in an inclusive educational environment. In our study, we used the following tools: A WebQuest created by teachers as the primary teaching method; teachers' comments after presentations for a qualitative assessment of language and professional skills development; a Likert-scale survey of students to collect quantitative data on their impressions and the effectiveness of the method and a Likert-scale survey of teachers, which allowed us to assess the implementation of WebQuests from the perspective of teachers.

The experiment was conducted at the Educational and Rehabilitation Institution of Higher Education "Kamianets-Podilskyi State Institute", the only institution in the region specializing in educating students with special needs. The study was conducted by 24 3rd year students of the Computer Technology major under the guidance of two ESP teachers, a group supervisor, and a specialist from the Faculty of Socio-Psychological Activities, Rehabilitation, and Professional Education. The experiment lasted in the spring semester of 2024.

Given the limited number of teaching hours in the discipline "English for Special Purposes" (18 hours per semester), WebQuests were selected for independent work outside class time. Familiarization with WebQuest technology and presentation defence occurred during practical classes, and communication was maintained through a Viber group. The experiment consisted of several stages:

1. *Initial stage*: familiarization of students with the WebQuest technology; development of two professionally oriented WebQuests by ESP teachers: "Artificial Intelligence and the Future of Programming" and "Developing Startup in the IT Sphere"; choosing a topic that the student liked by voting.

2. *Main stage*: adaptation of the WebQuest considering the inclusive approach (large font, badges, subtitled videos and audio versions of materials); use of interactive resources (MindMeister for mind maps, Quizlet for learning new vocabulary); providing students with the opportunity to choose a convenient format for completing tasks: oral, written or video recording; the result of the work was the preparation of an Elevator Pitch - a short presentation of a startup idea lasting up to two minutes.

3. *Final stage*: Presentation of student projects and their formative assessment by teachers; providing recommendations for improving communication skills and using professional vocabulary.

III. RESULTS AND DISCUSSION

To illustrate the formative assessment of students, we summarized the feedback from the instructors who participated in the experiment:

A. Foreign Language Instructor:

"Approximately 70% of participants demonstrated the ability to use professional vocabulary in their presentations correctly. I want to highlight the students' creative approach to developing mind maps for mastering industry-specific terminology, facilitating better material retention. It is also important that most participants understood and followed the Elevator Pitch format, showcasing their ability to concisely and convincingly present ideas in English. For further improvement, I recommend practicing the integration of professional terminology into real-life communication scenarios."

B. Group Supervisor:

"The lively communication among participants indicates high student engagement with this work format. The reward system using badges proved to be an effective motivator, maintaining student interest throughout all stages of the tasks. Creative assignments fostered critical thinking, teamwork, and self-directed learning skills—essential for future IT specialists. Given this positive experience, I recommend implementing similar formats to integrate language training with professional education."

C. Social Pedagogue:

"The WebQuest proved effective in creating an inclusive educational environment. Thanks to various task formats (oral, written, video), students with special educational needs could choose the best method and highlight their strengths. This format promotes communication skills and supports the principles of inclusive education."

A survey was conducted among 24 students and four instructors to evaluate the experiment's effectiveness. The student questionnaire focused on three key criteria:

1. Interest in Learning (including motivation and engagement in the process).

2. Development of Communication Skills (assessing confidence in English communication and improving teamwork skills).

3. Mastery of Material (applying professional vocabulary in practical situations).

The survey results are presented in Table 1, which lists the parameters of foreign language competencies assessed on a five-point Likert scale (from 1 to 5). The number of respondents, percentage ratio, and average score are indicated for each parameter.

TABLE 1 TABLE 1 TYPE STYLES

Category	Skills	1	2	3	4	5	Mean
Interest in Learning	motivation	8%	1 2 %	2 5 %	2 9 %	2 5 %	3.67
	engagement in the process	8%	1 7 %	2 5 %	3 3 %	1 7 %	3.83
Development of Communication Skills	assessing confidence in English communication	0%	1 2 %	2 5 %	3 7 %	2 5 %	4.04
	assessing confidence in English communication	4%	8 %	2 9 %	3 3 %	2 5 %	4.00
Mastery of Material	applying professional vocabulary in practical situations	4%	8 %	2 1 %	3 3 %	3 3 %	4.08

Analysis of the data obtained shows that most students demonstrate a moderate to high motivation to study (average score — 3.67), which is a positive trend. At the same time, a small percentage of students with a low motivation level was recorded, indicating the need for additional measures to attract them.

The overall indicator of student involvement in the educational process indicates positive dynamics. However, some respondents noted difficulties in integrating into the educational process. This shows the need to improve approaches to stimulating active student participation.

The indicator of students' confidence during communication in a foreign language using web-quest technology (average score — 4.04) deserves special attention, which indicates the effectiveness of interactive teaching methods. In addition, respondents positively assessed the aspects of teamwork, although the results indicate the presence of potential for further improvement in this area.

A significant part of the experiment participants emphasized that WebQuests contributed to using professional vocabulary practically, an essential factor in forming professional foreign language competence.

The results of the teacher survey, presented in the form of a histogram (see Figure 1), allow us to formulate several important conclusions regarding the effectiveness of implementing WebQuests in the educational process of students of technical specialties, particularly future software engineers in an inclusive academic environment.

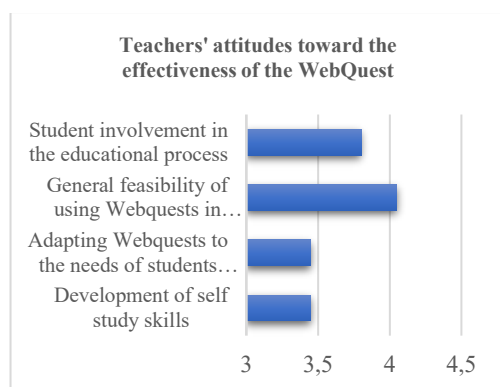


Fig. 1. Teachers' attitudes toward the effectiveness of the WebQuest.

All parameters assessed by teachers demonstrated relatively high results with minimal deviations, confirming the effectiveness of web quests in teaching a foreign language to students of IT specialties. The average score of 3.80 for involving students in the educational process and 4.05 for the appropriateness of using WebQuests indicates the high interactivity of the methodology and its compliance with the needs of students of technical fields. This is especially important for forming professional foreign language competencies of future IT specialists. Although teachers highly appreciated the interactivity of WebQuests, the aspects of developing

independent learning skills (3.45) and adapting to the needs of students with special educational needs (3.45) received average ratings. This indicates the existing potential for improvement in these areas. In particular:

- Developing students' independence requires integrating additional support tools, such as interactive prompts, micro-learning modules, and gamification elements to stimulate interest.
- Adapting for students with special needs requires more flexible technological solutions, for example, using platforms that can customize the interface or implementing tools to support students with sensory or cognitive impairments.
- Learning organisation in an inclusive educational environment requires methodological changes and material and technical base improvements. The use of WebQuests revealed the need to update equipment to create equal access to educational materials for all students.

An important recommendation is to involve scientific and pedagogical workers in international projects with the subsequent use of grant funds for the modernization of the educational environment. This will ensure access to modern equipment and technologies necessary for inclusive learning. Despite the expectations of rapid development of independent work skills, the results showed that students still demonstrate dependence on the teacher, in particular through frequent requests for help when completing web quest tasks. This emphasizes the importance of gradually forming lifelong learning competence by integrating reflection, self-control and self-assessment into the educational process.

The opinions of authoritative scientists and language practitioners agree that WebQuest technology positively impacts the development of foreign language competencies [5] – [11]. Our study is consistent with the results of an experiment [12] on teachers' attitudes to using WebQuests in teaching a foreign language to IT specialists. 87.09% of teachers approve of introducing WebQuests and support partially replacing traditional teaching methods with this technology.

Our results also confirm the importance of developing professional communication skills in foreign languages. At the same time, our study is distinguished by the specificity of the educational environment: we consider WebQuests an effective tool for improving foreign language competence in an inclusive academic environment, particularly for students with special educational needs. However, this does not exclude applying the study results in non-inclusive universities.

One of the requirements for a modern higher education institution is compliance with the principle of barrier-free learning. As a flexible format, WebQuest can be adapted to professional specifics and effectively used in professional foreign language classes for students without special needs. At the same time, implementing WebQuests in an inclusive environment requires additional adaptation of this technology to students' needs. The study provides

examples of online servers that ensure the convenience of using WebQuests by students with special needs.

Student work was assessed in a formative format: participants received feedback in the form of recommendations and wishes from teachers regarding presentations in the Elevator Pitch format. The keywords of these recommendations — professional vocabulary, creative approach, industry terminology, mind maps, Elevator Pitch, badges, professional communication, and principles of inclusion — reflect the main results of implementing WebQuests in the educational process.

The results of the student and teacher survey were unanimous: most students noted the use of professional vocabulary in practice, and teachers emphasized the appropriateness of using WebQuests in an inclusive environment and their effectiveness in increasing student engagement in the learning process.

IV. CONCLUSIONS

1. Analysis of literary sources on the Semantic Scholar platform revealed a limited number of publications devoted to using WebQuests for teaching a foreign language of professional orientation to engineering students and their application in an inclusive educational environment.
2. Their adaptation to students with special educational needs is necessary to use WebQuests effectively in an inclusive university environment. An example of creating such a WebQuests is given in our article. It includes an optimized interface, audio and video support, a reward system, and a convenient and understandable task format.
3. The formative assessment results were reflected in the teachers' recommendations. Analysis of the keywords of these recommendations indicates an emphasis on the practical use of a foreign language in a professional context, which is vital for future IT specialists. In addition, the teachers emphasized the appropriateness of modern methods for mastering new professional vocabulary and optimizing the educational process.
4. According to students, the introduction of WebQuest technology into ESP teaching contributes to the development of communication skills in a professional context. Teachers, in turn, noted this technology's compliance with the inclusive learning format and recorded increased student activity in the learning process.

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Model of Successful Digital Transformation of Higher Education Institutions

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Abstract— The significant impact of the recent global health crisis, combined with the possibility of using digital technologies to conduct online learning, represents an unprecedented opportunity to transform higher education on a European and global scale. We are all part of the digital world and the phenomenon of e-learning will be persistently present and further developed. The expectations are to build a sustainable model that will continue to be applied after overcoming all the challenges. The present article explores the theoretical concepts and the main features of the digital transformation of higher education institutions. As a result of the study some of the advantages and disadvantages of the digital learning have been analyzed. The scientific paper describes a model representing the six most important elements that drive the digital transformation process of the higher education institutions and overcome the identified disadvantages.

Keywords — *digital transformation, higher education, model, technologies*

I. INTRODUCTION

The digital revolution is changing the world at an unprecedented speed [1]. The use of new technologies and digital devices has begun to enter people's personal and professional lives at an ever-faster pace, and institutions have had to change in a timely manner to respond to the new conditions. All this requires a rapid transition to new organizational strategies, processes and functioning that reflect the dynamics of development of the external environment and the need for adaptation to it [2,3]. The necessary change is associated with carrying out a digital transformation - a process characterized by the widespread implementation and integration of digital technologies in all domains of public and economic life. Digital transformation is becoming a critical organizational strategy for survival and achieving competitiveness in today's market. The use of ICT's is becoming more and

more common in people's personal and professional lives. The global health crisis has confirmed the need to accelerate digital transformation in all economic and societal sectors and has shown in an undeniable way that making additional efforts to harness the potential of digital technologies is not only necessary but also mandatory for achieving competitiveness and sustainable development [4].

If used appropriately, digital technologies will reveal their huge potential in fostering effectiveness, quality and equity in higher education. A model of successful digital transformation of higher education institutions requires reframed national policies and action plans, an adequate strategic framework, financial support, additional training and quality assurance. A contemporary and sustainable digital learning ecosystem involves shared understanding among leaders and stakeholders about the dimensions of digital transformation.

The pandemic situation has accelerated the digitalization process of higher education, which started years ago [5,6], and higher education institutions must be able to provide quality education in conditions of digital transformation, dynamic technological innovations and accelerated changes in the educational model. Digital transformation is no longer seen as just a future trend, but is becoming a critical organizational strategy for survival and competitiveness in the modern global world.

II. MATERIAL AND METHODS

The aim of this paper is to explore the theoretical concepts and the main features of the digital transformation of higher education institutions. As a result of the study some of the advantages and disadvantages of the digital learning have been analyzed. A model representing the six most important elements that drive the digital

Online ISSN 2256-070X

<https://doi.org/10.17770/etr2025vol3.8538>

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transformation process of the higher education institutions have been presented. Descriptive and comparative analysis have been used in the study, applying qualitative data review.

III. RESULTS AND DISCUSSION

A. Definitions of the main terms

"Digital transformation" could be defined as the set of necessary digital processes aimed at strategic change in an individual organization. The important thing here is that digital transformation is about more than just digital processes.

Digital transformation has been defined as "a process that aims to improve an entity by triggering significant changes to its properties through combinations of information, computing, communication, and connectivity technologies" [7].

Digitization can be seen as part of digital transformation, and additional components include the right strategic planning, trust building, organizational learning, etc. [8].

Therefore, digital transformation is understood as the set of digital processes necessary to bring about a change that will allow higher education institutions to successfully introduce the use of digital technologies.

The characteristics of higher education institutions operating in the context of digital transformation are as follows:

- need to create special departments for digital technologies in the administrative structure of the higher education institution;
- opportunities to use mobile digital devices for access to the electronic database by employees, teachers and students;
- making decisions on the use of digital resources for conducting, regulating and controlling educational activities;
- implementation of faster interaction between providers and users of educational services as a result of the use of digital technologies;
- creation of new opportunities for organizational and social interaction between the employees of the organization and the participants in the educational process;
- need for knowledge about modern digital devices and e-learning platforms;
- ability to apply digital technologies in management practices, becoming a mandatory competence for all participants in the educational process [9].

Digital readiness involves teachers' and students' "preparedness and ability to use digital technologies for learning and teaching purposes" [10]. Digital literacy, self-efficacy, organizational culture and the attitudes toward digital transformation are some of the factors influencing digital readiness [11].

Digital learning is the core of the digital transformation of higher education institutions and "can be seen as part of the ecosystem of modern higher education" [12].

B. Advantages of digital transformation

Digital transformation offers a number of opportunities for educational institutions, some of which remain unused.

- Reduction of costs for consumables and transportation

Digital learning saves time and travel costs for students and teachers, as well as the inconvenience and stress associated with traveling to the educational institution. Working and learning in a digital environment reduces paper documents and operating costs due to storing documents and educational materials in the cloud.

- Opportunity to train students from all over the world

Digital learning enables educational institutions to be competitive in a globalized world and provides access to millions of students who could enrol and train without geographical restrictions. The shared digital space is also a suitable tool for creating a social network, allowing teachers and students to communicate effectively. The use of new technologies in the learning process will also attract the so-called "digital generation", which is familiar with the latest innovations in the digital world, uses mobile devices and expects to learn in a modern way.

- Access to learning materials from anywhere in the world and at any time

In the last two years, there has been a general improvement in the quality and quantity of online resources and learning materials. Learning in a digital environment allows access to published materials or participation in online lectures from anywhere in the world.

- Improved communication

Ineffective communication has caused huge losses for organizations due to misunderstanding of processes and ways of working. Learning in a digital environment is a solution for creating channels for effective communication, because it allows the organization, employees, teachers and students to connect and communicate with anyone and at any time. Easier interaction between students and teachers during lectures is also achieved by using the "chat function" of the e-learning platform. Through simultaneous communication and universal access to all students and employees, transparency in the educational institution and the conduct of the learning process is increased. The digital environment also allows for more creativity, sharing ideas and receiving feedback, and better communication helps in the successful management of conflicts.

- Social inclusion

The digital environment allows for the inclusion of certain disadvantaged categories of students - e.g. people with physical or other disabilities; people who take care for a family member. Education is also democratized by providing access to students who live in remote places and

do not have the opportunity to travel to the educational institution. Learning in a digital environment also helps to avoid possible discrimination based on age, race or physical disabilities.

- Cultural diversity

Cultural diversity in a digital environment has a positive effect on the development of intercultural competence of students. The different experiences of the trainers encourage creativity and viewing problems from different perspectives, so that diverse opinions are explored and taken into account.

- Environmental benefits

The benefits for the environment include reduction of traffic and pollution in large cities; protecting the environment by reducing the release of harmful emissions.

C. Disadvantages of digital transformation

Research on digital transformation shows that there are various problems and challenges for which solutions have not yet been found.

- Lack of social interaction

A very important element is missing in the digital environment: social interaction. The sense of community can be lost as a result of distance, and the emotional component and gestures are missing when sending messages. The emergence of psychological problems related to isolation or limited social interaction is also common, despite the strengthening of psychological support services implemented by many universities in 2020. To solve these problems, face-to-face meetings or video calls are necessary.

- Lack of support

Like all other systems, organizations are in a state of constant change. Every attempt of change leads to the corresponding distortion of the processes in the company in different planes than before. Resistance to change represents one of the challenges in the process of digital transformation. Technological progress requires radical organizational change, proactive leadership, adequate planning, effective communication and enough resources.

- Digital competence of academics and/or students

A number of difficulties may arise for teachers and students who are not familiar with the various digital tools and cannot use them effectively in the learning process [13-19]. The digital skills are prerequisite of a successful process of digital transformation.

With regard to higher education, it is emphasized that the digital competence of teachers significantly affects digitalization in educational institutions and is related to the synchronization of students' educational needs, their personality traits, curricula, learning process management and digital competence. With a view to introducing effective digital integrated training, it is necessary to prioritize the development of the academic staff and the

increase of their technological competence. The digital competence of students also significantly influences the introduction of new technologies in education by harmonizing digital learning methods, intercultural interaction and equal access to higher education. This applies with particular force to Bulgaria, bearing in mind the data on the percentage of individuals with basic or above basic digital skills of Bulgarian citizens (Table 1).

TABLE 1 INDIVIDUALS WITH BASIC OR ABOVE BASIC OVERALL DIGITAL SKILLS (PERCENTAGE OF INDIVIDUALS) [20]

GEO (Labels)	Time	
	2021	2023
European Union - 27 countries (from 2020)	53,9	55,6
Belgium	54,2	59,4
Bulgaria	31,2	35,5
Czechia	59,7	69,1
Denmark	68,6	69,6
Germany	48,9	52,2
Estonia	56,4	62,6
Ireland	70,5	72,9
Greece	52,5	52,4
Spain	64,2	66,2
France	61,9	59,7
Croatia	63,4	58,9
Italy	45,6	45,7
Cyprus	50,2	49,5
Latvia	50,8	45,3
Lithuania	48,8	52,9
Luxembourg	63,8	60,1
Hungary	49,1	58,9
Malta	61,2	63,0
Netherlands	78,9	82,7
Austria	63,3	64,7
Poland	42,9	44,3
Portugal	55,3	55,9
Romania	27,8	27,7
Slovenia	49,7	46,7
Slovakia	55,2	51,3
Finland	79,2	81,9
Sweden	66,6	66,4

Considering the critical importance of students' digital competence, it is necessary to make decisions at the political level and take the necessary measures to increase it, with a view to successful technological adaptation.

It is noteworthy that the digital competence in Bulgaria is at a low level and this can be seen from the presented data for the period 2021-2023, the comparison with other European countries and the average level for the European Union (55,6% for 2023). It is necessary to take urgent measures to increase the technological competence in Bulgaria. Increasing digital competence is a priority at both European and national level, and its importance for digital transformation and higher education is key. Investments in the development of people and their digital skills will be

repaid many times over, and the whole society will benefit from the positive effects.

The digital competence of the academic staff and students significantly influences the introduction of new technologies in education by harmonizing digital learning methods, intercultural interaction and equal access to higher education. The rapid technological progress requires the adoption of a proper legal framework, especially concerning the creation of digital learning content. Concerning the digital competence of teachers, the European Commission's Digital Competence Framework for Teachers (DigCompEdu) defines and describes "the skills that teachers should acquire in order to teach and introduce innovations through the use of digital technologies" [21].

- Program characteristics

Certain difficulties are encountered in teaching subjects with experimental or practical activities such as medicine, nursing, fine arts, architecture, engineering, etc. Students and researchers in the humanities and social sciences also face a number of challenges when access to libraries with fully digitalized resources is not provided.

- Technological challenges

Socio-economic divide, which makes it difficult to conduct the learning process and the participation of teachers and students who do not have modern mobile devices or access to high-speed internet. Using paid programs for preparing assignments or other learning activities is also a challenge for students.

- Lack of attention and concentration

Some students, especially younger ones, find it difficult to focus during long online lectures in the same way as in face-to-face classes.

- Equipment and maintenance costs

Organizations must allocate funds for appropriate equipment (hardware and software), as well as for maintenance and updating [1,16,18,22-25]. Due to the continuous improvement of technology, additional costs are also required for employee training. In the process of adapting to changes in new systems, it is possible to deteriorate the participation in the learning process and performance of students and teachers who are not so familiar with new technologies. At the same time, if the wrong digital platform is implemented, this can have a negative effect on the overall learning process.

- Data security and privacy protection

All devices – desktops, laptops and tablets – require the same protection because they may contain critical information for the educational institution and their use must be monitored to avoid cyber threats or information loss. The security and privacy risks could hinder the entire process of digital transformation [13,15-17, 23]. This requires additional protection and maintenance of information technology, as well as costs for network security. Cyberattacks can have an extremely negative

effect on the organization and stakeholders. Despite increased efforts to maintain security, there is always a risk of attacks that can be carried out by both outsiders and employees with access to information. Password protection and access to information are challenges that add costs to the educational institution.

- Loss of interpersonal communication skills

The use of mobile phones, sending messages and emails has largely replaced live communication. Interpersonal communication is fundamentally different in a digital environment. At the same time, sending messages and using virtual video platforms significantly reduces traditional communication. Face-to-face and group meetings are becoming obsolete as educational institutions rely on digital environments to conduct learning. The lack of physical communication and social interaction can lead to a sense of isolation and an inability to complete face-to-face tasks.

- Dependence on technology

Teachers and students can become very dependent on technology to perform their daily tasks. The majority of educational organizations rely on computer technology and its smooth functioning. If a system failure occurs, it can interfere with the activities of one or more teachers, as well as disrupt the learning process or the work of employees in the institution as a whole. Restoring computer systems provides additional costs for the organization and therefore it is necessary to plan available resources to cover these costs in the event of a crisis of any nature.

The described disadvantages of the digital transformation require special attention and methods for overcoming them. One possible solution could be the proposed model of digital transformation of higher education institutions.

D. Model of digital transformation of higher education institutions

An adequate and modern management vision implies massive use of all new trends and technological renewal of educational institutions, which is able to qualitatively change the process of education development. Such a contemporary vision starts with an analysis of students' expectations, followed by development of human resources and change management in order to introduce innovative technologies, services and business models in an organization with proactive leadership and positive culture.

The process of digitization of higher education can be represented by a model that describes the relationship between six distinct elements:

- Expectations/experience of students - before undertaking digitization, it is necessary to know the expectations, behaviour and experience of the main users of educational services - the students. Treating them in response to their needs is essential for any educational institution;
- Human resources are the critical part of the digitization process. It is necessary for the

organization to be able to attract talent and have qualified professionals who are also committed to the organization and the achievement of its goals. Educational institutions that invest in their employees, commit to their development and respect their ideas, build loyalty in them that makes managing change much easier. Digital technologies have already widely entered the educational sphere, but the important thing is not to forget who we are. Technology must be used to create meaningful experiences that reach students, faculty, and staff at a deeper level, connecting human to human;

- **Change** - any transformation is fundamentally about change and to be successful, people must support it. That is why an adaptive, flexible, and adequate way is sought to implement changes in an already functioning system, such as any organization. Resistance to change is one of the challenges in the process of digital transformation [1,6,15,17,22,25-32]. Resistance to change can be defined as an individual or group reaction aimed at thwarting or delaying attempts at change. Resistance itself can take many different forms and manifestations – from intelligent, subtle and invisible undermining of change or blocking of information to active actions, such as strikes. There are different forms of resistance: resistance to the content of the change – for example, to a specific change in technology; resistance to the process of change - this refers to the way in which the change is presented to employees or the way in which it is acted upon, rather than to the change itself. Leaders need to be aware of the importance and strength of resistance in order to be able to react adequately when it is detected. In general, the reasons for resistance can include things like: loss of control, shock from the new, uncertainty, insecurity, anxiety and fear regarding acquired status and competence. As wishful or taken from good textbooks it may sound, it is important to try to identify the reasons for resistance. Thus, efforts to redirect employees' energy towards constructive actions can be focused and much more successful. Which inevitably reflects on their motivation. Change is always difficult and requires strategy and communication with employees to provide the right tools and environment for change to succeed. If done effectively, it will take the organization to the next step of digital transformation;
- **Innovation** – transformation and innovation are interconnected and interdependent. Innovation is a necessary condition for digital transformation and requires a space of open communication, freedom for creativity and collaboration. Innovation must be constant to create new and improve existing services, products or processes;

- **Leadership** – for a change to be successful, it must be led. The lack of proactive leadership is one of the barriers in front of digital transformation [6,15,17,19,25,27,33,34]. The role of leaders is to lead by example, to be proactive. Technology is evolving rapidly and leaders must act in a timely manner. All other options need to be explored, not just digital transformation;
- **Culture** – organizational culture is more important than the choice of technology. Digital transformation cannot happen without the right organizational culture. If the organizational culture is too conservative, it would be difficult to go through a process of digital transformation [15,17,24,26,33,35]. By creating an open space where employees and students have positive experiences, where people matter, change is planned and innovation is central, the organization will be led to a culture where it transforms itself. University culture significantly influences the introduction of digitization in the learning process. The socio-technical perspective, technological leadership and learning outcomes are relevant. Various studies have observed the tendency for positive organizational cultures to provide adequate support and encouragement for the use of technology in the learning process.

The various parts of the digital transformation process are interconnected and relate in a circular model. The presented model in Fig. 1 consists of six elements that interact with each other:



Fig. 1. Model of digital transformation of higher education institutions

Students' expectations are related to more effective communication and collaboration with better digital services, offering the possibility to study from everywhere and without time limitations [36]. In response to these expectations higher education institutions should focus on innovative teaching and research, digital learning, flexible curricula development and personalized courses and experiences [17]. Meeting the students' expectations means also that teachers need to provide more innovative teaching, research and management experiences [17], while ensuring the quality of education. Higher education

institutions have to face the technological and financial constraints along with providing and maintaining the necessary infrastructure. Innovation is related to introduction of new technologies, curriculum modernization, digital educational content creation and re-engineering of business processes. Leaders should introduce and implement the change, driven by digital technologies, using effective business strategies while improving the organizational efficiency in higher education institutions.

Fostering such digital transformation requires building a culture of active participation by students, faculty, and administrators to support the change. A number of educational institutions in the EU face additional challenges as well, including financial and technological constraints. Public higher education institutions will also need to function in the situation of reduced public funding, while experiencing a drop in the number of students due to the recent and ongoing financial crisis. Investments will also be needed to improve the technical capabilities of European higher education institutions. Despite all these challenges, educational institutions in the EU are rather optimistic regarding the digital transformation. In a recent survey of institutions from all countries of the European Higher Education Area, most universities confirm that they “plan to explore new ways of teaching (92%) and improve its digital capacity (75%) after the crisis” [19].

In order to move to more sustainable model of e-learning, educational institutions need to utilize the existing technologies to reinvent learning processes, transform the roles of the traditional faculties and focus on quality through reinvention and the self-renewal of the educational service model and teaching methods. The digital transformation of higher education institutions could be successful only when all the stakeholders participate actively in the process.

IV. CONCLUSION

The present paper examined the concept of digital transformation along with the advantages and disadvantages of the process in the higher education institutions. As a result of the identified disadvantages, a circular model of six elements have been developed. The described model represents one possible solution for overcoming the challenges in the process of digital transformation of higher education institutions. In view with the rapid technological development all the organizations need to go through a digital transformation.

The digital age affects all participants in the educational process: both individuals and higher education institutions could not avoid the radical changes that technology initiated. Stakeholders are not even presented with a choice - it is inevitable to adopt and implement new, completely different approaches to digital practices that were considered unthinkable for most institutions in the recent past.

ACKNOWLEDGMENTS

The article has been made possible with the financial support of UTP – Sofia – NID Project.

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Analysis of the Main Factors for the Digitalization of Higher Education

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Abstract— The implementation of digital technologies and the global network impacts virtually all areas of life in the modern world. Higher education is no exception, and this requires an analysis of the entry of new technologies into education, as well as a review of existing strategic documents at the national and European level. The digital transformation is becoming a critical organizational strategy for survival and achieving competitiveness in higher education. The aim of the scientific paper is to identify the main factors influencing the process of digitalization and to mark the progress of the EU member states in this field. Descriptive and comparative analysis have been used in the study, applying quantitative data review. The analysis includes the political, socio-economic, organizational, educational and technological factors that influence the process of digitalization of higher education.

Keywords — *higher education, digitalization, factors, technologies*

I. INTRODUCTION

The diffusion of new information and communication technologies, which we have witnessed over the past decade, leads to a completely new dynamic and complex reality within which political, economic and social development unfolds.

The implementation of digital technologies and the global network impacts virtually all areas of life in the modern world. Higher education is no exception, and this requires an analysis of the implementation of new technologies into education, as well as a review of existing strategic documents at the national and European level. Special attention is now being paid to appropriate curricula, programs and tools so that higher education institutions can meet contemporary national and global challenges and provide support in the field of digital technologies, as well

as in the development and acquisition of digital competence.

The rapid introduction of information and communication technologies and the pandemic situation led to radical changes in the structure, organization and functioning of the higher education system and institutions [1,2]. The social distancing requirements imposed as a result of the global health crisis, have contributed to the increasing spread of learning in a digital environment, which has become an alternative to the face-to-face form.

The growing use of digital technologies by young people is seen as a major topic in 21st century and raises a number of questions related to the place of these technologies in modern life and their impact on the future [3,4]. The introduction of multimodal and digital technologies in the learning process is constantly increasing. These forms of knowledge transfer and means of communication are becoming common practice in university halls, combined with traditional educational technologies, such as lectures and the use of textbooks.

The process of digitalization of higher education rapidly evolved in the last years which caused a growing scientific interest to the topic [5-13]. There is vast research in the field of implementation of digital innovations in higher education, along with the factors affecting the process of digital transformation.

The inevitable development of the educational ecosystem and the change in service delivery and communication networks have caused the rapid implementation of technology and innovation [11]. The complex and interconnected nature of digital technologies enhance digital learning [5]. The lack of digital literacy represents an important challenge both for teachers and students [6,14-26]. Growing number of researchers study the emerging technologies like artificial intelligence (AI),

Online ISSN 2256-070X

<https://doi.org/10.17770/etr2025vol3.8539>

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virtual reality (VR), augmented reality (AR), Internet of Things (IoT), blockchain and their integration in the learning and teaching process [27-32].

The implementation of AI generated tools in higher education will transform the existing organizational models and involve a completely new approach to improve both the internal processes of course delivery and enhance the provisions of education quality while building new digital models for academic and administrative government.

II. MATERIALS AND METHODS

The material includes a scientific review of the process of digitalization of higher education and the main factors influencing the process. The political, socio-economic, organizational, educational and technological factors have been reviewed. Descriptive and comparative analysis have been used in the study, applying qualitative and quantitative data review.

III. RESULTS AND DISCUSSION

A. Definition of the main terms

The terms "digitization", "digitalization" and "digital transformation" are used interchangeably and it is necessary to distinguish between them (Fig. 1). The term "digitization" is defined as "the process of changing from analogue to digital format" [33] and is a purely technical process. "Digitalization" describes a distinct process (societal, operational or economic) and could be defined as "the process of using digital technologies and information to transform business operations" [34]. This definition could also be related to higher education. Bloomberg summarizes the three concepts as follows: "We digitize information, digitize processes and roles that define business operations, and digitally transform business and its strategy" [35].

Digitalization of education includes its modernization, reform and transformation, as well as solving problems and making decisions with the help of digital technologies [36].



Fig. 1. Concepts of digitization, digitalization and digital transformation.

Source: Massachusetts Institute of Technology (MIT)

According to researchers, digital technologies should be introduced in all areas of education, teacher training, educational infrastructure, methodology, teaching materials, as well as management at all levels and all sectors of the education system [37].

Digital technologies offer possibility for optimizing the learning process and improve the level of knowledge

acquiring. Interactive tools support educators in introducing innovative approaches, including case studies, experimental and research work, simulation games, and more. The use of the listed methods leads to more efficient assimilation of information, development of "appropriate skills and work in an emotionally comfortable environment that stimulates motivation to learn, the birth of new ideas and creativity [38]".

The concept of "education 4.0" is related to the vision and future of learning and teaching, where "digital technologies, personalized data, open-source content, connectivity" [13] lead to innovative thinking and creativity. Increased awareness, computational thinking, digital learning and digital literacy for academics and students have to be fostered through relevant curriculum and operations.

The digital transformation of higher education is closely related to acquiring and improving the digital competence of both, students and teachers. Digital competence is an extensive holistic concept that encompasses technological skills in a broader perspective.

According to the European Commission "digital competence" refers to "effectively and critically use information and technology for training, self-development and active participation in society [39]". The conceptual reference model of the digital competence is presented in Fig. 2.

The DigComp framework 2.2. encompasses five different areas:

- Information and data literacy;
- Communication and collaboration;
- Digital content creation;
- Safety;
- Problem solving.



Fig. 2. The DigComp Conceptual reference model [40].

Source: Joint Research Centre

The set goal of the European Commission is that "by 2030 at least 80% of all adults will have basic digital skills and that there will be 20 million specialists in the field of information and communication technologies in the European Union" [41].

With regard to the rapid technological development, as well as with the trend of ever-growing internationalization of higher education, the introduction of digital learning will

turn into a common practice. In view of the need for digital transformation of higher education, it is necessary to review the factors related to this process.

B. Factors for digital transformation of higher education

- Political factors

Digital technologies have enormous potential to help increase the quality, equity and effectiveness of higher education. Realizing the full potential of digitization requires a rethinking of the policy framework, including ways of funding, additional training and quality assurance. An adequate strategic framework of digitization, monitoring and ensuring quality education is needed.

The EU Digital Education Action Plan 2021-2027 [42] has two main priority areas - promoting the development of a highly effective digital education ecosystem and improving the digital skills and competences needed for digital transformation. Clear steps to achieve the priorities thus defined are also indicated. The renewed Digital Education Action Plan contributes to the European Commission's priority - "Ready for the Digital Age" - and is a key factor in realizing the vision of building a European Education Area by 2025 [42].

At national level, a Strategy for the development of higher education in the Republic of Bulgaria for the period 2021-2030 was adopted, as well as an Operational Plan for its implementation [43], which foresees the creation of digital curricula and new interactive digital resources. It is also planned to introduce modern, flexible and effective forms of training. In view of the digital transformation, all curricula and programs must be completely changed by 2029. The Operational Plan also envisages the inclusion of practical disciplines in artificial intelligence (AI), augmented reality (AR) and artificial reality (VR); a significant increase in electronic distance learning programs is also planned. To provide the necessary technical equipment that will be used in interactive and digital learning, funding is provided under the Program for Scientific Research, Innovation and Digitalization for Smart Transformation 2021-2027, as well as from the budgets of higher education institutions.

The European Commission's vision for Europe's digital transformation by 2030 is set out in the Communication "Digital Compass: The European Roadmap for the Digital Decade" and the governance framework put in place to achieve the digital goals - "Road to the Digital Decade".

It is necessary to take measures regarding the implementation of the Action Plan in the field of digital education (2021-2027) and to support the sustainable and effective adaptation of the European education and training systems to the digital era. The same measures are also necessary for the application of the Strategy for the Development of Higher Education in the Republic of Bulgaria 2021-2030 and the Operational Plan for it.

Digital transformation affects every aspect of people's lives, providing enormous possibilities for "a better quality

of life, innovation, economic growth and sustainability, but it also creates new challenges for the structure, security and stability of societies and economies" [42]. As the digital transformation accelerates, the European Union outlines "how its values and fundamental rights should be applied online in the recently adopted European Declaration on Digital Rights and Principles for the Digital Decade [42]".

- Socio-economic factors

Competition among higher education institutions

Competition among higher education institutions is a significant factor influencing the introduction of digital technologies into the educational process. The modern environment is characterized by ever-increasing and intensifying competition between universities, and it is imperative for higher education institutions to adapt to changes through digital transformation. This would also lead to a wider presentation of higher education institutions on the international educational scene and the attraction of talented students from all over the world.

Education costs

Expenses represent a factor that significantly influence the digitization of higher education by reducing them while maintaining the quality of education. Cost reduction is associated with digitization in higher education, and academics see e-learning technologies as the best innovation to reduce training costs [44]. Various authors point out that the transition to digital technologies in higher education can invert the cost curve [45].

Generational differences

The majority of current, and especially future students, belong to the so-called digital generation. Learning with the help of new technologies will be closer to their way of obtaining knowledge, acquiring skills and developing competences. At the same time, the flexibility in the educational process will increase, the efficiency of work in the classroom and outside will be improved, and there will be greater opportunities for active engagement of students, use of innovative methods and the student-centred approach to learning.

Social inclusion

The digital environment allows the inclusion of certain categories of disadvantaged people - e.g. people with physical or other disabilities, as well as students who live in remote settlements and do not have the opportunity to attend the chosen higher education institution. Achieving digital transformation would ensure equal access to higher education and democratization of higher education. Learning in a digital environment also helps to avoid possible discrimination based on age, race or physical disabilities.

- Organizational factors

Organizational culture

University culture significantly influences the introduction of digitization in the learning process. The

socio-technical perspective, technological leadership and learning outcomes are relevant. Various studies have observed the tendency for positive organizational cultures to provide adequate support and encouragement for the use of technology in the learning process.

Organizational effectiveness

As a result of the digital transformation within higher education institutions, an increase in the efficiency of interaction between individual structural units within a given university is observed.

- Educational factors

Quality assurance

The quality of higher education can be understood as a set of specific opportunities of the higher education institution and the degree of their implementation. Improving the quality of higher education is a major strategic goal in Bulgaria, as everywhere in the world, great attention is paid to issues of improving the quality of higher education with regard to the digital transformation.

The concept of quality assurance in the field of higher education in a broad sense is understood as a balanced compliance of higher education with diverse needs, goals, requirements, norms (standards).

In order to make use of the full potential of digitalization, it's necessary to consider the adoption of new policy framework, including ways of public funding, further training and quality assurance. An adequate strategic framework for ensuring quality education in digital environment is needed.

Digital competence of academics

Digital competence of academics has enormous impact on the digitization in higher education and is related to the synchronization of students' educational needs, their personality traits, curricula, learning process management and digital competence. With a view to introducing effective digital integrated training, it is necessary to prioritize the development of the academic staff and the increase of their technological competence.

Digital competence of students

Students' digital competence significantly influences the introduction of new technologies in education by harmonizing digital learning methods, intercultural interaction and equal access to higher education. Considering the critical importance of students' digital competence, it is necessary to make decisions at the political level and take the necessary measures to increase it, with a view to successful technological adaptation.

- Technological factors

Diffusion of technologies

The introduction of new technologies significantly influences the digitization of higher education through the integration of creativity, smart devices, augmented reality and the use of the "flipped classroom" method.

Infrastructure

The availability of adequate infrastructure has an impact on the process of digital transformation of higher education. Information technology infrastructure has a direct positive effect on the successful introduction of digital educational technologies [46].

Learning platforms

A number of higher education institutions have already begun to modernize their educational process, introducing the use of e-learning systems (platforms). The options available to universities when choosing a platform are ever greater. Both free and paid e-learning systems and platforms for conducting virtual lectures and classes are available. A system unique to the relevant higher education institution, specially developed for its needs, could also be used.

Data security and privacy protection

In view of the strict regulatory provisions on cyber security and protection of personal data, higher education institutions must invest in additional measures to protect information and data in the context of the introduction of digital technologies in the educational process and digital transformation. It is also necessary to pay attention to the protection of information, as this applies to e-learning platforms, existing learning materials, tests, sensitive information, as well as to internal communication in the organization.

The various factors affecting the digitalization of higher education are summarized in Table 1.

Along with the factors influencing the process of digitalization of higher education, there are still some challenges that need to be faced in order to utilize the full potential of the information and communication technologies.

TABLE 1 CLASSIFICATION OF THE FACTORS AFFECTING THE DIGITALIZATION OF HIGHER EDUCATION

Number	Type of factors	
	General	Specific
1.	Political factors	European strategic documents National strategic documents
2.	Socio-economic factors	Competition among higher education institutions Education costs Generational differences Social inclusion
3.	Organizational factors	Organizational culture Organizational effectiveness
4.	Educational factors	Quality assurance Digital competence of academics Digital competence of students
5.	Technological factors	Diffusion of technologies Infrastructure Learning platforms Data security and privacy protection

D. CHALLENGES AND FUTURE PERSPECTIVES IN THE PROCESS OF DIGITALIZATION OF HIGHER EDUCATION

The introduction of digital technologies in higher education globally began decades ago and varies significantly across higher education systems, as evidenced by the large amplitudes in the indicators of online learners in the higher education systems of OECD countries [47]. When digital technologies were initially introduced, their use was still limited. Many teachers in higher education institutions used existing systems only to publish curricula, distribute teaching materials and assignments, and maintain semester assessment information, while students received access to teaching materials, announcements, or assessment information.

The pandemic situation led to a sudden need for timely digitalization of higher education, forcing educational institutions to make a rapid transition to online learning. Providers of e-learning platforms had to respond to the fundamental change in the requirements of teachers and students. The use of virtual classrooms increased by 3600% in March 2020 and by 9000% at the end of September 2020 [48]. This outcome was mainly driven by the massive transition to e-learning platforms and online courses.

The abrupt transition to virtual learning in different countries has been accepted patiently and flexibly by teachers and students, although neither has perceived the experience as satisfactory. Teachers are dissatisfied with the lack of consultation with management during the transition to distance learning, as well as the increased workload in developing online learning materials and the students' need for more support in the virtual learning process.

A study conducted by the European Students' Union shows that students prefer face-to-face interaction with teachers [49]. As a result of the extraordinary and rapid transition to distance learning, many students perceived it as incomplete and unsatisfactory. Lectures and practical classes were not always replaced by an online equivalent. Other challenges were related to a significant increase in workload and assignments, the lack of a good internet connection, suitable learning space and adequate learning materials.

Similar problems were identified in a study conducted among 400 students, synthesizing the following negative aspects of e-learning [50]:

- often distance learning consists of publishing learning materials and an asynchronous form of learning or broadcasting a lecturer's lecture;
- limited access to high-speed Internet;
- communication is often interrupted by excessive use of Internet services or insufficient technical support in higher education institutions;
- many students use mobile devices during their studies, where the possible functions differ from those of computers with a screen;

- not all students have access to paid programs that are required to complete various assignments. In cases where licensed software products are used in higher education institutions, students cannot use them outside the educational building;
- many students report an increased number of assignments and hours spent in front of the computer;
- learning becomes an independent process; students encounter difficulties in understanding the educational material;
- teachers require the use of a camera during exams, but not all students have one on their home computers;
- students are worried about their ability to successfully absorb knowledge in the new format; it is also more difficult for them to participate in online discussions;
- real communication with teachers and colleagues is not taking place;
- decreased motivation for learning at home is observed;
- it is difficult for students to learn on their own and they lack real communication with the teacher;
- the time difference must also be taken into account in synchronous e-learning and the participation of students from different time zones.

The analysis of the above-mentioned challenges in the digitalization process illustrates the necessity of adequate measures application, considering the provisions of the Action Plan in the field of Digital Education (2021-2027) and in support of the sustainable and effective adaptation of the education and training systems of European countries to the digital age. The same measures are also needed at national level aiming at implementation of the Strategy for the Development of Higher Education in the Republic of Bulgaria 2021 - 2030 [43] and its Operational Plan.

Higher education systems are expected to undergo a process of increasing digitalization in the planning of the educational process, the teaching and learning process, assessment and educational statistics. An adequate response to the need for a more effective and widespread use of digital technologies will require higher education institutions to create a new generation of educational environments. The digital educational environment of the near future must be adapted for the use of mobile devices, offer conditions for better group work during the educational process and support interactive classrooms. Teachers will have more complete access to student statistics and will be able to better identify their educational needs and the difficulties they encounter; they will have better assessment options and improved models for

continuing professional development in the use of the digital educational environment.

The challenges facing the digitalization of higher education worldwide include the need for significant investments in hardware and software and sufficient time to train academic staff in the application of new technologies. Educational institutions still need to make use of the full potential of the information and communication technologies to create a more flexible and rich educational process. Higher education institutions need to guide the process of digitalization, so as to ensure that the services provided by educational technology providers meet the needs of teachers and students.

IV. CONCLUSION

In the present article have been examined some of the mainstream research concepts regarding the digitalization of higher education. The main factors influencing the process of digitalization were identified, including political, socio-economic, organizational, educational and technological factors. Some of the challenges in the process have been analyzed along with the future perspectives.

In conclusion, we can point out that there is a significant difference between the development of the educational ecosystem and the ecosystem of digital technologies. Like any other ecosystem in nature, the educational ecosystem needs balance to be sustainable. The pandemic situation has shifted the focus on digital technologies behind e-learning, with too little attention being paid to people and teaching methods. Data and technology are just tools, but the focus should be on the people in the system. If we limit ourselves to using technology to copy traditional pedagogical approaches, it will not serve the students well. A complete revision of the used training methods and the possibilities of new technologies should be done.

ACKNOWLEDGMENTS

The article has been made possible with the financial support of UTP-Sofia – NID Project.

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Leveraging ChatGPT to Develop Critical Thinking Through Mathematical Problem-Solving in ESP Classes

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Abstract—The article highlights the influence of artificial intelligence (AI), in particular ChatGPT, on the development of critical thinking during ESP (English for Specific Purposes) classes. The authors' main goal is to investigate the effectiveness of using ChatGPT to foster critical thinking skills of prospective mathematicians and engineers. Great attention is paid to the methodology of using ChatGPT to solve mathematical problems through the prism of problem-based learning by combining theoretical research and its practical implementation in the educational environment. The results of a survey, conducted among students, showed that 89% of respondents agree that ChatGPT is an effective tool for developing critical thinking skills. Participants noted an improvement in their ability to divide complex tasks into stages, analyse data and get valuable explanations of complex concepts. The article focuses on the possibilities of integrating AI to solve mathematical problems, analyse complex concepts, and develop reflection skills. It's also highlighted the benefits of using ChatGPT in education, mainly for increasing students' confidence, interactivity of the learning process, and expanding opportunities for the development of analytical thinking. At the same time, the authors emphasise on the necessity of critical analysis of AI results and the need to improve approaches to its integration into the educational process. As it can be seen ChatGPT has a positive impact on the formation of an individual approach to learning and the development of interdisciplinary skills. The results of research describe the significant potential of

AI in modernising the educational process and improving its quality.

Keywords—Artificial intelligence (AI), ChatGPT, critical thinking skills, ESP (English for Specific Purposes) classes, problem-based learning (PBL), prospective mathematicians and engineers.

I. INTRODUCTION

Artificial intelligence (AI) technologies are progressing so fast that human beings cannot catch up with them at times. They are slowly creeping into every corner of people lives and have transformed the way how they live and work. AI is not a threat to humans, but rather an assistant that can help succeed in work, make routine matters easier and have time for creativity. It's no longer a buzzword; it is a part of human life.

The impact of AI on humanity depends on how people use it. The importance of it is revealed in a number of new innovative technologies like machine and deep learning. It's possible to see its wider impact in a lot of other sectors like education, healthcare, manufacturing and hospitality, which strengthens its potential further.

AI is reshaping life as people know it, and the education system is no different. It has emerged as a powerful solution to face the challenges in education and speed up the progress toward the achievements of SDG 4

Online ISSN 2256-070X

<https://doi.org/10.17770/etr2025vol3.8540>

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(Sustainable Development Goal 4). AI allows technology to be able to collect and analyse data to inform teachers on students' engagement, learning progress, and well-being. Likewise, there are digital applications and tools whose features allow to interact with the teacher and monitor progress individually [1].

According to Harry and others [2], AI in education refers to the use of artificial intelligence technologies, namely machine learning and natural language processing, to improve the educational experience. It makes use of algorithms that analyse data, look for patterns and make predictions, which allows teachers to customise learning for the individual student. Nguyen [3] emphasises on the necessity to compare different approaches of AI usage which can improve education and create new AI applications in education that will include personalized recommendations for students.

AI has a great potential in the field of education. In his research Wu [4] investigates how AI transforms educational curriculum by shaping and responding to the educational demand within diverse contexts. First of all, it ensures personalized learning, especially for students with diverse needs, which can help them to improve their outcomes, progress at their own pace and in a manner that works with their preferred learning style [5] – [6]. It can be used for realisation of inclusive education that can increase students' accessibility, allowing more and more disabled students to participate in the classroom [7]. AI has a capacity in spreading ecohumanism in educational settings, personalizing experiences, and enhancing ecological literacy while bridging interdisciplinary collaboration [8].

One of the directions of modernisation and innovative development of education is STEM-oriented approach aimed at enhancing the popularisation of engineering and technical professions which increases interest for choosing specialty, motivates for studying disciplines which form the basis of STEM education. It refers to the teaching of complex scientific disciplines combined into one: science, technology, engineering and mathematics. It focuses on educating, developing talents and professional skills, as well as scientific literacy, innovation awareness and ability [9].

The necessity to concentrate on integrated curriculum in the field of science, technology, engineering and math became evident by research studies conducted by Rumjaun, Barcelona, Belbase and others [10] – [12]. Their findings are connected with the implementation, priorities, prospects, processes and problems of STEM education. It is shown that by integrative approaches to teaching and learning is possible to improve students' interest and progress in STEM learning skills.

ChatGPT is considered nowadays as the main AI tool and is ranked confidently among the top global educational trends. With its rapid spread, teachers and researchers around the world are worried that it will prevent the development of analytical and critical thinking skills and affect students' academic integrity [13]. In turn,

students claim that ChatGPT increases their confidence to ask meaningful questions, analyse information and understand complex concepts, and encourages deep, reflective thinking and intellectual engagement [14].

The development of critical thinking skills is impossible without problem-based (PBL) learning, as it encourages students to analyse, research and find solutions to complex problems [15]. This method promotes critical thinking, logical reasoning and innovative decision making. Students become active participants in their learning process rather than absorbing facts and information passively, they examine alternative opinions and analyse real data to draw their conclusions [16]. Moreover, problem-based learning allows not only to deepen knowledge but also to develop flexibility of thinking and the ability to make informed decisions in a situation of uncertainty. That's why, it's very important to find effective strategies for facilitating the successful adoption of PBL in diverse educational contexts [17].

Using ChatGPT during ESP (English for Specific Purposes) classes for solving problem-based tasks creates new perspectives for critical thinking development. The interaction with AI allows to explore problems, discuss various ways of solving them and evaluate other opinions. ChatGPT serves as an assistant that provides real-time solutions, helps to clarify requests and create models for effective problem solving. Such method enhances not only the English language skills but also logic, the ability to set goals and assess the adequacy of selected solutions in the context of the learning situation.

This research *aims* to investigate how leveraging ChatGPT in ESP classrooms can foster critical thinking by guiding prospective mathematicians and engineers through mathematical problem-solving tasks relevant to their specific academic or professional spheres.

II. MATERIALS AND METHODS

This study applied a mixed-methods approach, using quantitative and qualitative methods to evaluate the effectiveness of using ChatGPT in developing critical thinking skills through mathematical problem-solving and analyse the results of students' activities in ESP classes.

There is a wide variety of tools and platforms that can be used to solve mathematical problems, such as: Wolfram Alpha – an online platform that uses AI to solve integrals, mathematical equations, differential equations, etc.; Microsoft Math Solver – a free tool that helps with math, including equations, graphs and other problems; Symbolab – popular tool for solving equations step by step; ChatGPT – a chatbot for arithmetic operations, proportions, fractions, calculation of percentages, linear equations and inequalities. After analysing functions of these resources, it was decided to use only ChatGPT for the research, because it covers the largest scope of usage: basic mathematics, algebra, geometry, trigonometry, higher mathematics and statistics.

Working on the study, the concept of using AI to solve mathematical problems was formed, which included 5 main stages “Fig. 1”. Following the proposed instruction, the students were able to test their critical thinking skills, which include the ability to compare, analyse and evaluate information from any source; to see problems and ask questions; to put forward hypotheses; to make a conscious choice and justify it.

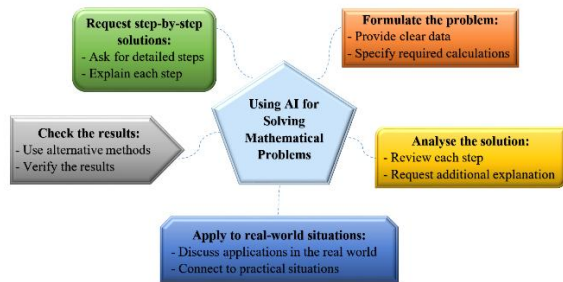


Fig. 1. Using AI for solving mathematical problems.

Solving a certain mathematical problem, students followed step-by-step instructions on how to formulate a request correctly for receiving the necessary information. After processing the request by ChatGPT, they had to analyse the received information if it met their requirements. They had to observe what critical thinking skills they applied at each stage of the work.

Example of using ChatGPT for solving mathematical problems:

Stage 1. Formulate the problem:

Objective: Analyse and understand the problem, break the problem into its component parts, recognise the main and secondary aspects of the task, determine the available information and its relevance, consider possible methods of solving the problem, identify hidden details and understand the context of the task, develop critical thinking skills.

Instructions: State all the information and parameters of the mathematical problem clearly; specify required calculations.

Result: Interaction between a student who learns how to form correctly a request and ChatGPT that responds to the student's request “Fig. 2”.

The stage of problem formulation is the basis that determines the direction of further solution. An unclear or incorrect formulation of the problem can lead to a false result, even if the subsequent steps are performed correctly.

Stage 2. Request step-by-step solutions:

Objective: Ensure a logical sequence of calculations and operations, develop the ability to assess the correctness of each step, improve the accuracy of calculations by focusing on individual actions, identify and correct errors at the early stages, and strengthen basic knowledge and rules of mathematics.

In a right triangle, the legs are in the ratio of 3:4, and the hypotenuse is 25 cm. Find the area of this triangle.

To solve this problem, follow these steps:

- 1. Understand the problem**
 The triangle is a right triangle, with the legs in the ratio 3:4 and the hypotenuse given as 25 cm.
 Let the lengths of the legs be $3x$ and $4x$, where x is a common multiplier.
- 2. Use the Pythagorean theorem**
 The Pythagorean theorem states:
 $(\text{leg})^2 + (\text{leg})^2 = (\text{hypotenuse})^2$
 Substitute the values:
 $(3x)^2 + (4x)^2 = 25^2$
 $9x^2 + 16x^2 = 625$
 $25x^2 = 625$
- 3. Solve for x**
 $x^2 = 25$
 $x = 5$
- 4. Calculate the lengths of the legs**
 First leg = $3x = 3 \cdot 5 = 15$ cm
 Second leg = $4x = 4 \cdot 5 = 20$ cm
- 5. Find the area of the triangle**
 The area A of a right triangle can be given by:
 $A = \frac{1}{2} \cdot (\text{first leg}) \cdot (\text{second leg})$
 $A = \frac{1}{2} \cdot 15 \cdot 20 = \frac{1}{2} \cdot 300 = 150 \text{ cm}^2$

Final Answer:
 The area of the triangle is: 150 cm²

Fig. 2. Sample of interaction between the student and ChatGPT at stage 1.

Instructions: Make a request that each step of the decision process was outlined; make sure that each step is accompanied by an explanation of clarity.

Write down each step in detail and explain what we are doing and why

Here is the detailed step-by-step explanation for solving the problem:

Step 1: Understand the problem
 We are given:
 1. The triangle is a right triangle.
 2. The two legs of the triangle are in the ratio 3:4.
 3. The hypotenuse is 25 cm.
 The area of a right triangle can be calculated using:
 $A = \frac{1}{2} \cdot (\text{leg 1}) \cdot (\text{leg 2})$

But first, we must find the lengths of the two legs.
Step 2: Represent the lengths of the legs
 Since the legs are in the ratio 3:4, let their lengths be $3x$ and $4x$, where x is a common multiplier. This allows us to represent the legs proportionally. Using a variable x ensures the ratio 3:4 is maintained, and we can use it to solve for the actual lengths of the legs.
Step 3: Apply the Pythagorean Theorem
 The Pythagorean theorem for a right triangle states:
 $(\text{leg 1})^2 + (\text{leg 2})^2 = (\text{hypotenuse})^2$
 Substitute $3x$ and $4x$ for the legs, and 25 for the hypotenuse:
 $(3x)^2 + (4x)^2 = 25^2$
 Simplify:
 $9x^2 + 16x^2 = 625$
 $25x^2 = 625$

This equation lets us solve for x , the common multiplier, which will give us the actual lengths of the legs.
Step 4: Solve for x
 Divide both sides of the equation by 25:
 $x^2 = 25$
 Take the square root of both sides:
 $x = 5$

The value of x is now determined, and we can use it to calculate the actual lengths of the legs.
Step 5: Calculate the lengths of the legs
 Substitute $x = 5$ into $3x$ and $4x$:
 1. First leg:
 $3x = 3 \cdot 5 = 15$ cm
 2. Second leg:
 $4x = 4 \cdot 5 = 20$ cm
 Now we know the lengths of both legs, which are required to calculate the area.
Step 6: Find the area of the triangle
 The formula to calculate for the area of a right triangle is:
 $A = \frac{1}{2} \cdot (\text{leg 1}) \cdot (\text{leg 2})$
 Substitute the values of the legs (15 cm and 20 cm):
 $A = \frac{1}{2} \cdot 15 \cdot 20$
 $A = \frac{1}{2} \cdot 300 = 150 \text{ cm}^2$

This formula calculates the area by multiplying the base (15 cm) and the height (20 cm) and dividing by 2, as required for any triangle.
Final Answer:
 150 cm²

Fig. 3. Sample of interaction between the student and ChatGPT at stage 2.

Result: Interaction between a student who learns how to form correctly a request and ChatGPT that responds to the student's request "Fig. 3".

The request step-by-step solution stage is especially useful for beginners who are just mastering the method of solving problems. It provides analysis of complex problems that require a multi-step approach. Teachers are encouraged to teach students to think autonomously and understand mathematics, not just perform mechanically operations.

Stage 3. Analyse the solution:

Objective: Check the compliance of the solution with the conditions of the problem, identify possible errors in calculations or reasoning, verify whether the result meets the original objective of the task, understand the impact of individual steps on the final solution, identify more efficient methods of solving the problem.

Instructions: Go through the solution step by step to ensure accuracy; ask for further clarification if any part of the solution is unclear.

Result: Interaction between a student who learns how to form correctly a request and ChatGPT that responds to the student's request "Fig. 4".

Step 3: Apply the Pythagorean Theorem

The Pythagorean Theorem may be a crucial property of right triangles, which states:

$$(\text{leg } 1)^2 + (\text{leg } 2)^2 = (\text{hypotenuse})^2$$

This means that the square of the lengths of the two legs of a right triangle adds up to the square of the hypotenuse. It applies only to right triangles and allows us to relate the three sides of the triangle.

We are given the hypotenuse (25 cm) and the ratio of the two legs (3 : 4). To find the actual lengths of the legs, we need to relate all three sides of the triangle. The Pythagorean theorem is the perfect tool for this.

Set up the equation

The legs are represented as $3x$ and $4x$, where x is the common multiplier maintaining the ratio 3 : 4. Substituting these expressions for the legs into the theorem, we write:

$$(3x)^2 + (4x)^2 = 25^2$$

By substituting, we ensure the lengths of the legs maintain the given ratio, while x scales them to their true size based on the hypotenuse.

Simplify the equation

Expand the squares of the terms:

$$(3x)^2 = 9x^2 \text{ and } (4x)^2 = 16x^2$$

Add these together:

$$9x^2 + 16x^2 = 625$$

$$25x^2 = 625$$

This gives us a single equation in terms of x^2 , which we can solve to find x . Solving for x will let us calculate the actual lengths of the legs.

Solve for x

To isolate x^2 , divide both sides by 25:

$$x^2 = 625 \div 25$$

$$x^2 = 25$$

Take the square root of both sides to solve for x :

$$x = \sqrt{25}$$

$$x = 5$$

The value of x tells us how much the legs $3x$ and $4x$ are scaled. Using this value, we can calculate the actual lengths of the legs.

By applying the Pythagorean theorem and substituting the given information, we reduced the problem to a solvable equation. Solving this equation for x allowed us to determine the true dimensions of the triangle while preserving the 3 : 4 ratio.

Fig. 4. Sample of interaction between the student and ChatGPT at stage 3.

Analysing the solution helps not only to check the correctness of the answer, but also to develop self-control, critical thinking and reflection skills. This stage provides a deeper understanding of the solution process and helps to improve the quality of further solutions.

Stage 4. Check the results:

Objective: Use backward calculation or alternative methods to verify the result, analyse the result for compliance with the initial conditions, find possible inaccuracies or shortcomings in the solution process, use simulations or simplified versions of the problem to confirm the result, develop skills of critical analysis of own work.

Instructions: Solve the problem using different methods to confirm the results; cross-check the results to ensure correctness.

Result: Interaction between a student who learns how to form correctly a request and ChatGPT that responds to the student's request "Fig. 5".

Do another calculation with a different solution method

Let's solve the problem using trigonometry as an alternative method. Here's how:

Step 1: Understand the problem
We know:
1. It's a right triangle.
2. The hypotenuse is 25 cm.
3. The legs are in the ratio 3 : 4.
We need the lengths of the legs to find the area.

Step 2: Use the ratio of the legs
The ratio of the legs is 3 : 4. This means the triangle corresponds to a scaled version of the well-known 3-4-5 Pythagorean triple. The hypotenuse (25 cm) matches a scaled version of the "5" in the 3 : 4 : 5 ratio.
Scale Factor:
The scaling factor can be determined by dividing the hypotenuse by 5 (the hypotenuse in the basic 3 : 4 : 5 triangle):
Scale factor = $\frac{\text{Hypotenuse } 25}{5} = \frac{25}{5} = 5$

Step 3: Calculate the lengths of the legs
To find the actual lengths of the legs, multiply the 3 and 4 from the 3 : 4 : 5 ratio by the scale factor (5):
1. First leg:
Length of first leg = $3 \cdot 5 = 15$ cm
2. Second leg:
Length of second leg = $4 \cdot 5 = 20$ cm

Step 4: Calculate the area
The formula for the area of a right triangle is:
 $A = \frac{1}{2} \cdot (\text{leg } 1) \cdot (\text{leg } 2)$
Substitute the values:
 $A = \frac{1}{2} \cdot 15 \cdot 20$
 $A = \frac{1}{2} \cdot 300 = 150 \text{ cm}^2$

Final Answer
The area of the triangle is:
150 cm²

Fig. 5. Sample of interaction between the student and ChatGPT at stage 4.

This stage is the final and crucial step in the problem-solving process, as it ensures that the result is correct, logical and applicable. It also contributes to the development of attentiveness, consistency and a responsible attitude to problem solving.

Stage 5. Apply to real-world situations:

Objective: Use the obtained solution to solve same or similar problems in real life, analyse how well the result meets the needs and conditions of the real situation, develop the ability to apply theoretical knowledge in practice and flexibility of thinking to adapt to different conditions, formulate proposals for optimising or improving the result, compare the expected and actual effect of the solution, recognize possible risks and consequences in a real-world context, form a positive attitude towards the use of the experience gained.

Instructions: Identify where the solution can be applied practically in the real world; relate the

mathematical problem to real-life contexts for better understanding.

Result: Interaction between a student who learns how to form correctly a request and ChatGPT that responds to the student's request "Fig. 6".

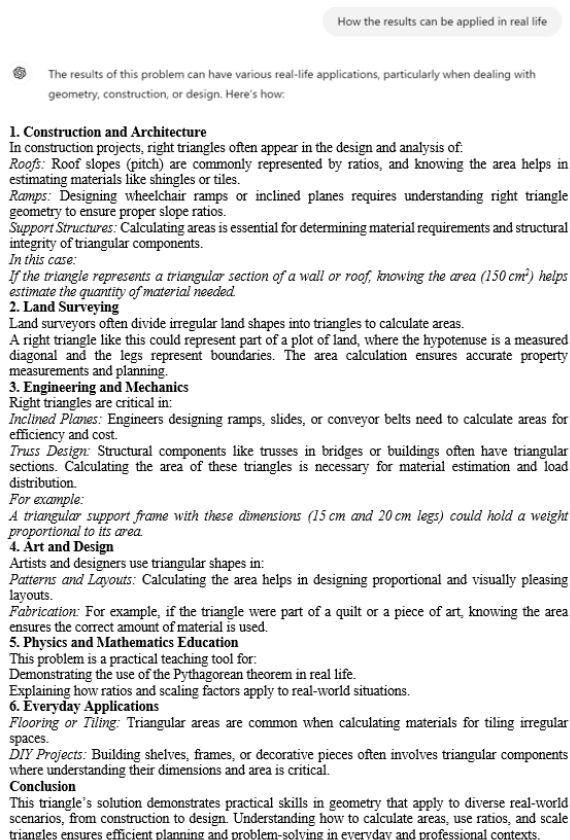


Fig. 6. Sample of interaction between the student and ChatGPT at stage 5.

This stage completes the problem-solving process, making knowledge more practical and valuable. It helps to consolidate the results, create new experience and increase competence in various fields of activity.

Participants:

The students of Vinnytsia Mykhailo Kotsiubynskyi State Pedagogical University took part in this study. The participants were 36 second-year students from the Mathematics and Information Technology educational programme. The students had an obligatory ESP course (2 academic hours per week during the second term of 2023-2024 academic year) according to the university syllabus with the ratio of classwork and self-study 1 to 2. They worked in a self-study mode for four months. The ESP classes were held offline and lasted 80 minutes. Students were informed about the goals, tasks, and conditions of study and participated voluntarily.

Procedure:

From the very beginning, all students attended an initial session to familiarise them with the objectives and

expectations of the study. They were given a tutorial on how to sign in and use ChatGPT effectively and were provided with the set of mathematical problems tailored to ESP classes. Over a four-month period, during classes at the university they worked weekly on problem-solving exercises using traditional resources such as textbooks, lectures and teacher's explanations. At home they used ChatGPT to solve mathematical problems interactively, get explanations, and explore alternative solutions. A special collaborative platform was created where students and teachers discussed the advantages and disadvantages of using ChatGPT for improving critical thinking, understanding of mathematical problems and influencing their instructional strategies.

Data Collection:

Both teachers and students participated in the study. Quantitative data was collected and analysed from problem-solving tasks, critical thinking assessments, and post surveys. Qualitative data, which included transcripts of interviews, was subjected to thematic analysis to identify patterns and insights related to the benefits and challenges of using ChatGPT in the context of ESP. In addition, a questionnaire survey entitled "Benefits of Using ChatGPT to Develop Critical Thinking" was conducted among students. The study followed ethical research practices. The participants' anonymity and confidentiality was ensured throughout the research process.

III. RESULTS AND DISCUSSION

While participating in the study, first of all, students had the ability to develop their critical thinking skills. They learned to evaluate the correctness of AI answers, to improve the ability to ask clarifying questions to AI and to analyse mathematical problems and check solutions. Secondly, they examined the role of ChatGPT in education, which helped them to understand complex mathematical concepts easier and form skills of collaboration with AI as a tool. They also faced with challenges and limitations, such as: problems with the accuracy of ChatGPT answers in complex mathematical problems and the need for critical analysis of the results.

After conducting in-depth case studies of prospective mathematicians and engineers and analysing the results of the questionnaire, it was examined how ChatGPT impacts learning (table 1).

As it can be seen from the table of results of the questionnaire, using ChatGPT had a clear positive impact on the development of critical thinking. 89% of the respondents believe that ChatGPT is an effective tool for the development of critical thinking. For instance, 36% "strongly agree" and 55% "agree" that ChatGPT improves these skills. 74% of respondents said that ChatGPT allows them to divide complex problems into smaller steps – an important skill that develops critical thinking. Overall, 82% of participants reported that ChatGPT improves their analytical and evaluative ability in processing information critically. 83% of respondents

TABLE I BENEFITS OF USING CHATGPT TO DEVELOP CRITICAL THINKING SKILLS

No	Benefits of Using ChatGPT	Strongly Agree (%)	Agree (%)	Neutral (%)	Disagree (%)	Strongly Disagree (%)
1	ChatGPT helps break down complex problems into manageable steps	10	74	10	4	2
2	using ChatGPT can improve the ability to analyse and evaluate information critically	25	57	3	10	5
3	ChatGPT provides valuable explanations that enhance understanding of challenging concepts	48	35	7	6	4
4	the feedback from ChatGPT encourages to explore alternative solutions to problems	20	66	7	4	3
5	ChatGPT helps identify logical errors or gaps in reasoning	22	50	12	10	6
6	using ChatGPT encourages to ask more critical and thoughtful questions	43	45	6	4	2
7	ChatGPT provides examples that enhance problem-solving and critical thinking skills	19	71	5	3	2
8	the interactive nature of ChatGPT makes it easier to understand complex ideas	39	43	8	6	4
9	using ChatGPT has increased confidence in tackling unknown or challenging problems	16	68	4	6	6
10	ChatGPT is an effective tool for developing critical thinking skills	36	55	5	3	1

feel that ChatGPT offers valuable and clarifying explanations to help improve their understanding of complex ideas. 86% of respondents agree that feedback from ChatGPT motivates them to explore alternative solutions to problems. 88% of participants said that ChatGPT helps them to formulate critical and thoughtful questions. The majority of those surveyed (84%) reported feeling more confident solving unknown or difficult problems using ChatGPT.

The analysis of students' answers proved that ChatGPT is an effective tool for critical thinking development in the ESP classes. The study results cohered with Nguyen [3], Donnell and others [5] conclusions that ChatGPT assists in examining information, comprehending intricate ideas, building a holistic strategy for activities and improving users' trust in solving complex challenges in the educational process. Overall, the study results are compatible with Harry and others [2], Wu [13] evidences that respondents who use ChatGPT as a learning and reflection tool have relatively high satisfaction while using it.

Thus, ChatGPT or other AI tool can be used in multiple ways to support the teaching and learning process, particularly as an interactive tool for facilitating understanding, engagement and critical thinking in the ESP classes. Below are some specific ways by which it can enrich teaching and learning in general:

1. Analysis of ideas and arguments. Submit the ideas or arguments to ChatGPT and ask it to review their logic or recommend other ways to solve the problem or alternative perspectives on the problem. It is possible to identify thinking weaknesses and shortcomings, develop an evaluation of one's own ideas, and improve arguments.

2. Evaluation of information and sources. Paste the article or news text in and ask ChatGPT to check facts or assess its reliability and objectivity. Though ChatGPT can't fact-check in real time, it can help indicate common errors or stereotypes. It builds critical reading and source evaluation skills.

3. Question formulation. Ask ChatGPT generate questions that can help better understand what you have just read or come up with complicated problems to solve that requires analysis. Learning how to ask questions encourages deep thinking and analysis.

4. Analysis of complex concepts. Make ChatGPT summarise a challenging concept in plain language or suggest an analogy for a complex phenomenon. This makes it easier to understand complex concepts and gives access to more data for their further analysis.

5. Consideration of alternative points of view. Offer a discussion on a topic to see different views then ask ChatGPT to evaluate these arguments and find weaknesses. This helps to learn how to take into account different points of view and improve the arguments.

6. Analysis of problems and solutions. Make ChatGPT break the task into smaller steps and suggest

potential consequences of solution. This contributes to a structured approach to problem solving.

7. Assessment of risks and uncertainties. Ask ChatGPT for risks or solutions in case of uncertain data. It aids in the predicting of problems and planning of actions in the face of uncertainty.

8. Scripting and modelling. Ask to simulate a situation that will help assess reaction about methods to test theories. This activates the capacity for modelling repercussions and exploring potential scenarios.

9. Learning from mistakes. Send made mistakes so ChatGPT can help correct them and provide ways to prevent typical errors. The errors analysis develops self-control and accuracy in thinking.

10. Self-reflection. Send a text or argument for feedback and ask ChatGPT to find cognitive biases in thinking. Reflection lead to improvement in the process of thinking and do not allow to make the same mistakes again.

IV. CONCLUSION

In this age of rapid technological development, such tools as ChatGPT are transforming our approach to learning, problem-solving and critical thinking. From analysing ideas and arguments to evaluating information and sources or exploring alternative perspectives, ChatGPT provides an accessible platform for elaborating intellectual processes. By breaking down complex concepts, promoting introspection, and simulating problem-solving scenarios, it empowers users to enhance their logic, assess risks, and gain insights from errors. This tool not only plays a crucial role in building analytical skills, but also helps the user to explore and examine a wide variety of topics.

The usage of ChatGPT in ESP classes is a valuable innovation in modern education, particularly for enhancing mathematical problem-solving. It serves as a catalyst for developing critical thinking skills by providing real-time feedback, generating diverse problem scenarios, and encouraging analytical discussions. It's known as a versatile tool for improving the learning process, its ability to simulate collaborative learning as well as adapt to different students' needs.

However, the use of ChatGPT should be lined up strategically with pedagogical goals, paying attention to guided learning and critical evaluation of the AI outputs. Teachers play an important role in ensuring that ChatGPT supplements traditional teaching methods, rather than replaces them. The study proved if this modern technology is integrated effectively, it can empower students to solve mathematical problems with greater confidence, foster both their language proficiency and problem-solving abilities in a dynamic and engaging learning environment.

The further research should be addressed the practical issue of incorporating ChatGPT in the educational process

of prospective mathematicians and engineers in order to develop different aspects of English communicative professionally oriented competency.

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Use of Comics in Enhancing Speaking Interaction Skills of Prospective Engineers in ESP Classroom

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Abstract—The article is devoted to the problem of teaching English for specific purposes (ESP) of engineering students. The research reports on the effectiveness of using comics as an innovative tool for enhancing English speaking interaction of engineering students in ESP classroom. Particular attention is paid to the use of online platforms for creating comics, as a means of improving professional English speaking skills in the context of engineering activities. It is noted that online resources for creating comics are accessible and easy to use, which makes it possible to integrate this method into the educational process. The advantages and disadvantages of using comics as a tool for enhancing speaking skills in the educational process are revealed. It is defined that comics allow the students to work with technical terms and the realities of professional communication by creating context based on engineering situations. Due to the visual component of comics, the students can more effectively understand the context of communication and build their speech strategies according to real-life situations. The study defines that using comics may require more preparation time and is not always suitable for every topic or type of learning activity. The research shows that although comics have a certain template, the tasks based on comics while learning English allow developing coherent foreign language speech, enriching students' vocabulary, analyzing the material read and identifying the main points. The use of comics enables engineering students not only to work actively with the text but also to develop their creative abilities by creating their own comics using modern Internet resources and mobile technologies. The findings suggest that working with comics not only increases the motivation of engineering students, but also provides interactive and dynamic learning that improves their English language skills.

Keywords—Comics, engineering students, English for specific purposes, English language skills, English speaking interaction.

I. INTRODUCTION

In today's globalized and integrated professional communications environment, engineers need not only to possess specialized technical knowledge but also demonstrate a high level of English communicative competence, particularly in the context of their professional activities. In this regard, learning English for professional communication is becoming an extremely important aspect of training future engineers.

One of the main problems in teaching English for professional communication is the low motivation of students to learn a foreign language, caused by the use of traditional methods that can seem monotonous and ineffective. In addition, the available educational materials often do not correspond to the real-life professional activities that students will face in their future careers.

The education system is currently undergoing significant changes due to certain prerequisites. One of the prerequisites is the generation of young people who are growing up in the digital era and who cannot imagine their lives without daily use of a mobile device. Their perception and assimilation of information require modern teaching methods.

We share the opinion of Dmitrenko and others [1] that the active use of language learning strategies plays a key role in helping students manage their learning, develop their speaking abilities, and boost their confidence and motivation to learn a foreign language. By applying these strategies, students become more autonomous and take greater responsibility for their learning process. As they use more strategies, they feel more confident, motivated, and independent in their language skills. In the ESP (English for Specific Purposes) classroom, the teacher's main task is to choose suitable methods and strategies that align with the students' needs and to guide them in effectively using these strategies to improve their

Online ISSN 2256-070X

<https://doi.org/10.17770/etr2025vol3.8541>

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speaking skills and foster greater autonomy in learning. The students are no longer interested in working with large amounts of information but rather learn much better short phrases or texts that contain images. The use of comics is best suited to provide engaging and lively lessons, where students have the opportunity to demonstrate their communication skills.

The use of comics in teaching English and other disciplines is becoming an effective tool for educators, so many meaningful scientific studies have been implemented in the educational process recently. Gudoshnyk [2], [3] considers comics as a phenomenon of mass culture and explores its popularization in Ukraine through the publishing market, specialized magazines and online reviews, and various thematic events dedicated to comics culture. Kolesnyk [4] considers comics as one of the types of visual art, which, depending on the genre of the comic, can be attributed to both literature and cinema. The author describes the influence of calligraphy on the poetics of comics (the skill of conveying the written word with the help of various fonts), choreography and theatre (facial expressions, gestures, various poses have become an expressive means of comics), cinema (borrowing the principle of storyboarding, plan and perspective).

Kosmatska [5] considers comics as a phenomenon of mass culture and draws attention to the completeness of the lines: the use of incomplete sentences, short emotionally expressive statements, addresses and exclamations. Dmitrenko and others [6] consider creolized texts, to which they also include comics, as a means of shaping adolescents' value orientations. Lavrenova [7] focuses on the possibilities of using comics in the educational process, namely, using comics to activate vocabulary, improving communication skills, organizing individual and group work. Semenova [8] believes that involving comics in the educational process affects the improvement of foreign language communicative competence and promotes the use of student-centered, competency-based, communicative, and sociocultural approaches in the process of learning foreign languages.

Apostolou and Linardatos [9] studied the effectiveness of digital comics in computer science classes to show how the use of comics contributes to successful learning. Aleixo, Matkin and Kilby [10] surveyed the educators about their experiences using comics in the educational process and analyzed their responses. The use of comics was considered only as a means of entertainment and had no educational value; the usefulness of using comics in education was to help students who needed additional support; the use of comics had not yet reached its pedagogical potential.

The formation of speaking interaction skills is a complex process, as it requires doing certain exercises to master dialogue unities, producing micro-dialogues and composing dialogues for several lines. Accordingly, this process will differ for each student, depending on their age, attention span and motivation for learning English.

Nikolaeva, Bihych, Borysko and Boretska [11] believe that the formation of speaking interaction skills is impossible without the development of students' speech, learning, intellectual, organisational and compensatory skills, which involves the ability to start a conversation, maintain it and end it while using the appropriate intonation, gestures, facial expressions, and the ability to switch from one topic of conversation to another. It also requires the ability to predict the interlocutor's possible remark, systematise and evaluate the information received during the conversation and respond accordingly; the ability to use various information and communication technologies and supports; the ability to respond quickly to the interlocutor's phrases and provide feedback; the ability to find ways to solve difficult situations that arise during the dialogue.

The development of speaking interaction skills becomes effective if students have a high level of speaking skills (the ability to use lexical, phonetic and grammatical material while listening and speaking), phonetic skills (the ability to perceive and recognise sounds, intonations and produce their speech in accordance with phonetic norms); lexical skills (the ability to recognise lexical units and use them in their speech); grammatical skills (the ability to recognise grammatical forms and structures and use them).

The term "comics" has many definitions, but they all state that it is an image that tells a story with dialogues and descriptions of events. The sequence of these images creates a narrative. The texts in these images are often placed in phylacteries – clouds or bubbles that convey the speech or thoughts of the comic characters [12].

Chykalova [13] reveals the advantages of using comics in the educational process. First of all, it is the capacity of information and the dynamism of its display that makes it possible to quickly and easily learn the necessary material through visual channels of information perception. The students can work with comics gradually, after viewing 2-3 panels of the comics, they can stop, discuss what they have read, determine whether all the lexical units and grammatical structures are clear. The students can try to predict what might happen next to the main characters. The scientist states that using this approach will encourage the students to improve their English proficiency.

Another advantage is the brevity and accuracy of the language in comics, which allows the use of simple words, phrases and short structures that are easy to read and remember. Working on a comic book will keep students active, as they will be constantly engaged in performing certain tasks aimed at developing reading, speaking, writing and listening skills. Comics can be an effective tool for organizing students' independent work, allowing them to create tasks that include working with the text and combining graphic and textual material.

The research aim is to substantiate the effectiveness of using comics in enhancing the speaking interaction skills of prospective engineers in the ESP classroom.

II. MATERIALS AND METHODS

Future engineers can develop their skills and abilities in foreign language communication while working with comics. If they work on creating a comic book, they have the opportunity to use various Internet services and use mobile technologies (smartphones, tablets, computers, mobile applications).

During our research, we used the website <https://www.storyboardthat.com/storyboard-creator>. It has a very wide range of options that can be used to create comics. The site menu provides options to select a background, customize the main characters, and choose bubbles in various shapes. When working with text, it is possible to adjust the font, size, and colour. For the main character images, the site offers opportunities for experimentation and creativity. The main characters can be people who lived in different eras and belong to different professions, monsters or mythical heroes, animals, shadows. Heroes can be placed in different poses – sitting, standing, talking; their appearance can be changed: from the colour of their hair and skin to the colour of their clothes; they can express different emotions.

There are a few limitations to using this site. Without registration, only three free panels are available for comic creation, which also restricts the selection of characters and backgrounds. Saving the created comic is not possible, with the only option being to take screenshots and save them to a device. Registering on the site unlocks a broader range of options for comic creation.

In the study, professionally oriented English vocabulary was taught to the prospective engineers through comics created using the aforementioned website. The first step involves selecting or creating a comic on a specific topic relevant to the students' learning objectives. Based on this comic, tasks are developed in which the students are required to fill in gaps with target words or expressions. Prior to completing the tasks, the students are provided with hints, such as the part of speech the word might belong to or the first letters of the word to be inserted.

Comics were also used to teach grammar in ESP classroom. The students were asked to complete tasks based on the comics, where they needed to use a verb in a certain tense form, or use a particular grammatical structure in a sentence. In these tasks, students were required to infer the meaning of the structure from the context.

The development of speaking interaction skills for prospective engineers was facilitated through dialogue-based activities. Initially, students were given tasks involving images of comics with missing dialogue from the main characters. They were asked to guess the possible content of the conversation, the setting, and the characters involved. After a general discussion, the same images were distributed, but this time with some dialogue lines already included. The students' task was to complete

the dialogue by adding the missing lines. To promote collaboration, the students were divided into groups, allowing them to work together to fill in the gaps with appropriate phrases. Finally, all possible dialogue versions were reviewed, and the most suitable one was selected.

Another variation of the speaking interaction exercise involves the task of establishing the correct sequence of cues. This activity was conducted in a distance learning format using Jamboard, where the students edited the cues provided by the educator. In a traditional classroom, students could be divided into teams to arrange the lines in the correct order, adhering to grammatical and punctuation rules. A time limit could also be set to increase the challenge. Once completed, the answers are reviewed and compared with the original comic strip. The final stage involves the students composing their own dialogue, providing an opportunity to demonstrate acquired vocabulary, grammar, and speaking skills.

The research was conducted with 28 second-year students majoring in Engineering at Vinnytsia Mykhailo Kotsiubynskyi State Pedagogical University. The training took place over one term in the 2023/2024 academic year and was carried out under standard conditions without any special selection of students, in two subgroups of 14 students each. The students were informed about the purpose and objectives of the experimental training. During the experimental phase, all students in the experimental groups used the same educational materials as those in the control group. The method of working with comics was applied during the training of the experimental group. All students were assessed using the same criteria, and speaking interaction tests were administered both at the beginning and at the end of the experimental training.

The students' speaking interaction skills were assessed according to the following criteria:

- 1) relevance of the dialogues created by students to the speech situation and the communicative task;
- 2) coherence of the presentation;
- 3) length of the speech;
- 4) reactivity;
- 5) language proficiency;
- 6) initiative in speaking interaction.

The results of students' speaking interaction based on comics were assessed using a learning coefficient, adapted to align with the specific requirements of speaking interaction skill development.

The students' answers were assessed on a scale that includes six criteria for evaluating the quality of the testee's dialogic speech. Each criterion was rated on a scale from 0 to 3:

- "0" – the criterion is absent;
- "1" – the criterion shows very weak indications;
- "2" – the criterion shows certain indications;
- "3" – the criterion demonstrates sufficient indications.

The learning coefficient is calculated using the formula $q = n : m$, where q is the learning coefficient, n is the score achieved by the test taker, and m is the maximum score for the task. To ensure more accurate results, the coefficient values should be expressed in hundredths.

The grade for creating and presenting a task in comics is given by comparing the learning coefficient with the grading scale.

TABLE 1 CORRELATION BETWEEN THE LEARNING COEFFICIENT AND THE LEVELS OF SPEAKING INTERACTION SKILLS DEVELOPMENT

<i>Levels of speaking interaction skills development</i>	<i>The learning coefficient</i>
High	0,85 - 1
Intermediate	0,75 - 0,84
Satisfactory	0,65 - 0,74
Low	0,64 and less

Although speaking interaction typically involves the interaction of two communication partners, each student was assessed individually in this study. The goal of experimental learning is to foster the personal development of each student, enabling them to engage in conversations not only with a desk partner or friends but also in various real-life situations. In real life, each student will need to quickly adapt to different contexts, initiate and maintain conversations, and respond appropriately in formal settings. Experimental learning focuses on changing communication partners, varying role tasks, considering students' interests and preferences, and providing feedback to improve the speaking interaction skills of both interlocutors after their interaction has concluded.

The learning coefficient during the pre-experimental phase was 0.68 for the control group and 0.66 for the experimental group. According to the correlation between the learning coefficient and the rating scale (see Table 1), these values correspond to the "satisfactory" level, indicating an insufficient development of speech and dialogic speech skills in both groups.

III. RESULTS AND DISCUSSION

At the beginning of our study, the students in both the control and experimental groups showed approximately the similar level of speaking interaction skills development. At the stage of the post-experimental assessment, after the experimental group students had worked with the comic-based methodology we proposed, a post-experiment evaluation was conducted. The results of this assessment showed that the learning coefficient in the control group increased to 0.71, while in the experimental group, it increased to 0.85. These results correspond to the levels of speaking interaction skills development categorized as "satisfactory" and "high," respectively.

After the experiment, the dialogues created by the students of the experimental group based on comics aligned well with the communicative situation. The students presented their thoughts accurately, logically, and coherently, with an increased length of the speech. The dialogues became more meaningful, and the responses met the general requirements. The interlocutors responded much more quickly to each other's remarks, using learned set phrases and active vocabulary. Furthermore, the initiative in the conversations also increased. Therefore, the dynamics of the individual criteria before and after the experimental assessment for both the control and experimental groups are presented in Table 2. The dynamics of achievement are marked with two symbols: "+" (indicating an improvement in the quality of the criterion) and "-" (indicating a decline in the quality of the criterion).

TABLE 2 RESULTS OF THE INDICATORS BY CRITERIA OF SPEAKING INTERACTION SKILLS DEVELOPMENT

<i>Indicators by criteria</i>	<i>Control group</i>			<i>Experimental group</i>		
	<i>before</i>	<i>after</i>	<i>dynamics</i>	<i>before</i>	<i>after</i>	<i>dynamics</i>
Relevance of the dialogues created by students to the speech situation and the communicative task	3,25	3,33	+ 0,08	3,41	3,75	+ 0,33
Coherence of the presentation	3,00	3,08	+ 0,08	3,00	3,58	+ 0,58
Length of the speech	3,08	3,25	+ 0,17	2,83	3,41	+ 0,58
Reactivity	2,50	2,66	+ 0,16	2,25	3,33	+ 1,08
Language proficiency	2,33	2,41	+ 0,08	2,25	3,33	+ 1,08
Initiative in speaking interaction	2,33	2,41	+ 0,08	2,08	3,00	+ 0,92

In the control group, no significant improvements in speaking interaction were observed based on the relevant indicators of individual criteria. As shown in Table 2, only minor changes occurred in the control group, with the most notable increases being in the volume of expression, which rose by 0.17, and reactivity, which increased by 0.16. The remaining indicator coefficients improved by 0.08.

It is evident that significant positive changes occurred in the experimental group. The greatest increase was observed in the success coefficient for reactivity and language proficiency in producing dialogues, with a rise of 1.08, followed by initiative in carrying out dialogic speech, which increased by 0.92. Additionally, the coefficients for the volume of expression and the logical coherence of thought presentation improved by 0.58,

while the coefficient for the alignment of the students' created dialogues with the communicative situation increased by 0.33.

TABLE 3 AVERAGE INDICATORS OF THE PRE- AND POST-EXPERIMENTAL ASSESSMENTS

Total number of students	Indicators by criteria						Indicators by all criteria	
	Relevance of the dialogues created by students to the speech situation and the communicative task	Coherence of the presentation	Length of the speech	Reactivity	Language proficiency	Initiative in speaking interaction	Total score	Learning coefficient
Experimental group								
Pre-experimental assessment								
14	3,41	3	2,83	2,25	2,25	2,08	15,83	0,66
Control group								
Pre-experimental assessment								
14	3,25	3	3,08	2,5	2,33	2,33	16,5	0,68
Experimental group								
Post-experimental assessment								
14	3,75	3,58	3,41	3,33	3,33	3	20,41	0,85
Control group								
Post-experimental assessment								
14	3,33	3,08	3,25	2,66	2,41	2,41	17,16	0,71
Maximum score								
14	4	4	4	4	4	4	24	1

The comparative analysis of the results before and after the experiment led to the conclusion of positive outcomes from the conducted research. The effectiveness of the proposed method for enhancing speaking interaction skills based on comics was confirmed (the average learning coefficient after the experimental training is 0.71 for the control group, compared to 0.68 before, and 0.85 for the experimental group, compared to 0.66 before). The obtained results provide a strong basis to assert that the dynamics of speaking interaction development, measured by individual criteria, is more positive and significant in the experimental group than in the control group.

Our research confirmed the idea presented by Lavrenova [7], Semenova [8], Apostolou and Linardatos [9] that the use of comics in the ESP classroom provides

an opportunity to develop speaking interaction skills, expand students' vocabulary, improve their phonetic, lexical, and grammatical abilities, to analyze reading material, highlight key points, demonstrate creativity, and foster innovative and critical thinking. Additionally, comics enhance motivation for learning. Due to visual and textual components, comics facilitate better language material acquisition and the development of professional communication skills.

The results of the conducted research confirmed the effectiveness of using comics as a method for teaching professionally oriented English to engineering students.

IV. CONCLUSION

The relevance of using comics in teaching English for specific purposes to prospective engineers is underscored by several factors. First, with the advancement of digital technologies, modern students possess a high level of visual literacy, enabling them to effectively engage with comics as an educational tool. Second, comics integrate lexical, grammatical, and communicative aspects of language, which are essential for developing professional language competence. They provide a valuable platform for learning specialized terminology and exploring speech situations relevant to the professional activities of engineers. Introducing comics into the educational process can serve as an effective strategy to enhance student motivation, foster interactive and contextually enriched learning, and support the development of the language and communication skills crucial for professional success.

The study revealed that there are potential challenges when working with comics. Comics can be difficult to understand if they feature a complex plot, multiple main characters, or if they include difficult vocabulary, intricate grammatical structures, or use of allegories and metaphors. When it comes to creating comics, a significant limitation may be the insufficient level of knowledge among both educators and students. This gap can hinder the effective integration of comics into the learning process.

The research shows that although comics have a certain pattern, performing tasks based on comics while learning English allows developing coherent foreign language dialogic speech, expanding students' vocabulary, analyzing the material read, and highlighting the main points. Using comics allows engineering students not only to actively work with the text, but also to develop their creative abilities by creating their comics using modern Internet resources and mobile technologies. The findings suggest that working with comics not only increases the motivation of engineering students but also provides interactive and dynamic learning, which improves their speaking, reading, writing, and listening skills in English.

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Engineering Students' English Proficiency Development through AR Technologies

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Abstract—This paper explores the implementation of Augmented Reality (AR) technology as an innovative tool for enhancing English language skills among engineering students. In the context of rapid technological integration into educational processes, AR emerges as a powerful instrument for creating an effective learning environment, particularly relevant for future engineers who will work with cutting-edge technologies. While this topic has been extensively researched internationally over the past decade, the application of AR in English language teaching for technical specialists remains understudied in the domestic educational space. This study aims to unveil the potential of AR applications and platforms for developing professionally-oriented language competencies among engineering students. The research analyzes the didactic capabilities of mobile AR applications and proposes a comprehensive set of exercises designed to develop technical vocabulary and communication skills in a professional context. Special attention is paid to creating immersive scenarios that simulate real industrial situations, where engineering students can practice professional English while interacting with virtual objects and delivering technical presentations. This study contributes to the growing body of literature on technology-enhanced language learning by demonstrating how AR can be effectively integrated into ESP (English for Specific Purposes) curriculum for engineering students. The findings suggest that AR-enhanced learning environments significantly improve students' engagement, technical vocabulary retention, and confidence in professional communication scenarios.

Keywords—augmented reality, engineering education, ESP (English for Specific Purposes), English proficiency, immersive technologies.

I. INTRODUCTION

In a modern technological world, where virtual and real merge into a seamless fabric, augmented reality (AR) is emerging not only as an innovative trend but as a powerful tool for enhancing English language learning skills. In this context, the role of augmented reality as an effective means of improving oral communication in English language classes for prospective Engineering Students becomes increasingly significant. By immersing themselves in an interactive environment, students gain opportunities to apply their communication skills in realistic situations, which promotes not only increased motivation but also the development of key linguistic abilities in their professional field.

Over the past decade, the application of augmented reality in education has garnered significant attention in the international academic community. Zhou [1] examined the impact of augmented reality implementation in college English classes, emphasizing its innovative approach and positive influence on the learning process. In the engineering education context, Ryani and others [2] conducted a comprehensive study with 127 engineering students, demonstrating significantly improved retention rates in technical vocabulary acquisition through AR applications. This finding was further supported by Huang and others' [3] research, which reported a 34% better retention rate in engineering vocabulary when using AR-

Online ISSN 2256-070X

<https://doi.org/10.17770/etr2025vol3.8542>

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enhanced learning methods compared to traditional approaches.

Bressler and Bodzin [4] investigated the potential of augmented reality in student assessment processes, while Liu and others [5] specifically focused on AR implementation for developing technical presentation skills among engineering students in China, noting marked improvements in confidence levels and mastery of professional terminology. The works of Bonner, Reinders, Godwin-Jones and others [6] – [8] explored the practical application of augmented reality in English language classes and proposed specific examples of tasks that stimulate active student participation.

More recent studies have focused on the integration of AR with Industry 4.0 requirements. Bano and others [9] demonstrated how mixed-reality environments can simultaneously develop both technical and linguistic competencies through simulated workplace scenarios. This approach has proven particularly valuable for engineering students preparing for modern industrial environments. Shkola [10] explored the role of augmented reality as an effective tool of developing speaking skills in English language classes.

AR has emerged as a transformative tool in teaching English for Specific Purposes (ESP) to engineering students, offering unique opportunities to integrate digital elements with real-world engineering contexts. As Garzon [11] noted, augmented reality enhances the real environment through computer-perceptual information to create an interactive experience that bridges theoretical knowledge with practical application.

Research by Sanak and Nabil [12] emphasized that augmented reality serves as an effective tool that motivates students to learn, promotes their engagement in the process, and facilitates the development of language skills. While these studies [13], [14] demonstrated the broad possibilities of augmented reality application in the educational process and its positive impact on English language learning outcomes, particularly in engineering education, domestic educators working specifically in foreign language teaching in Ukraine [15], [16], [17] have left this topic on the periphery of scientific research. This gap has motivated our chosen topic and defined its objectives.

The synthesis of these studies reveals a clear trend in the effectiveness of AR technology for ESP instruction, particularly in engineering contexts, where the combination of technical and linguistic elements creates a uniquely powerful learning environment. However, there remains a need for more comprehensive research in the domestic context to fully understand how these benefits can be best realized within our educational framework.

The study aims to unveil the potential of AR applications and platforms for developing professionally oriented language competencies among engineering students.

II. MATERIALS AND METHODS

The study employed a mixed-methods approach incorporating several research techniques. The research methodology incorporates literature analysis and synthesis, including a comprehensive review and systematization of scientific works, articles, and publications related to the research topic. To determine the effectiveness of applications and platforms, observational methods were employed. The researchers conducted an analysis of the advantages and disadvantages of using augmented reality applications and platforms in English language classes for future engineers studying at the university. This analysis included an assessment of the positive impact on student motivation, improvement of speaking skills, and identification of potential technical and pedagogical limitations.

Based on the research analysis results, specific tasks were developed for English language teachers that enable effective use of augmented reality platforms and applications in the classroom.

The research was conducted with second-year engineering students from Berdyansk State Pedagogical University and Vinnytsia Mykhailo Kotsiubynskyi State Pedagogical University, involving 24 participants during one semester. The ESP classes were held online and lasted 80 minutes. Students were informed about the goals, tasks, and conditions of study and participated voluntarily.

To reveal the impact of AR implementation in English language learning of engineering students, the survey was conducted among students at the end of the semester.

III. RESULTS AND DISCUSSION

The implementation of AR in engineering ESP courses demonstrated several significant advantages. Primarily, it enables the creation of immersive technical scenarios where future engineers can develop their professional communication skills in contextually relevant situations. These scenarios allow students to interact with virtual industrial equipment, conduct maintenance procedures, and deliver technical presentations in English, simultaneously developing both their technical comprehension and linguistic competence.

The integration of AR technology in engineering language instruction has shown particular effectiveness in three key areas. First, it significantly enhances technical vocabulary acquisition through visual and interactive engagement with engineering concepts. Second, it improves students' confidence in professional speaking situations by providing opportunities to practice technical explanations and presentations in a controlled yet realistic environment. Third, it develops critical professional communication skills through task-based learning scenarios that mirror real industrial situations.

For practical implementation, the Merge EDU platform has proven effective in engineering ESP contexts. This platform, available with a free educational license, supports the creation of technical AR models and enables virtual object manipulation in engineering-

specific scenarios. The platform's effectiveness was demonstrated through a series of technical presentation tasks where engineering students utilized AR to explain complex equipment operations and maintenance procedures.

The research findings indicate that AR-enhanced learning activities significantly improve student engagement with technical content while developing essential professional communication skills. For instance, when conducting technical equipment presentations using AR, students demonstrated improved mastery of specialized vocabulary and greater confidence in explaining complex technical processes in English. The interactive nature of AR technology also facilitated more natural and contextually appropriate language use in professional scenarios.

Furthermore, the implementation of AR in engineering ESP courses addresses a crucial need in technical education: the development of professional communication skills within authentic engineering contexts. The technology enables students to practice and refine their English language skills while engaging with technical content, creating a more integrated and efficient learning experience. This approach particularly benefits engineering students who need to develop both technical expertise and professional communication abilities simultaneously.

The gamification elements inherent in AR technology add an engaging dimension to technical communication tasks, transforming traditional language learning into an interactive professional development experience. However, it is crucial to maintain a balanced approach where technology serves as a tool for language acquisition rather than becoming the primary focus of instruction. The successful integration of AR in engineering ESP courses requires careful consideration of learning objectives, technical requirements, and pedagogical strategies to ensure optimal educational outcomes.

The study also revealed that AR-enhanced instruction particularly excels in developing students' ability to explain technical processes, present engineering solutions, and participate in professional discussions. These skills are essential for future engineers who will need to communicate effectively in international professional environments. The technology's capacity to create immersive, context-rich learning environments provides students with authentic opportunities to practice these crucial professional communication skills.

Engineering Equipment Maintenance AR Activity

Objective: Develop engineering students' speaking skills and use augmented reality to create 3D scenes demonstrating proper equipment maintenance procedures.

Materials: Merge EDU platform (free educational license), smartphones or tablets, internet connection, space for AR presentations, basic information about industrial equipment maintenance.

Procedure:

1. Ask students about their experience with engineering equipment maintenance and their thoughts on the importance of proper maintenance procedures in industrial settings.

2. Explain the concept of augmented reality and demonstrate how to work with the Merge EDU platform. Show how to manipulate 3D models, add annotations, and create maintenance scenarios.

3. Divide students into groups. Allow them to choose a piece of industrial equipment from the available AR models that they will need to maintain and, if possible, add relevant tools and safety equipment to the scene.

4. Task the groups with creating a short narrative describing their maintenance procedure scene, including various technical elements and safety considerations. Give them time to prepare.

5. Groups present their AR scenes to the class. The audience asks technical questions and provides feedback, evaluating how well the scenes convey proper maintenance procedures and safety protocols.

6. After presentations, students discuss what they learned, what they liked or didn't like, and write a brief technical reflection answering teacher-prepared questions about the maintenance procedures and communication challenges.

Students' assessment is based on their ability to: effectively collaborate within their teams, present maintenance procedures clearly and professionally, use appropriate technical vocabulary, demonstrate an understanding of safety protocols, reflect on the learning process, engage in technical discussions.

The activity helps engineering students develop both technical expertise and professional communication skills while creating an engaging, interactive learning experience that mirrors real-world industrial scenarios.

Another useful tool for English language teachers working with future engineers is the 3DBear AR app, which allows creating interactive presentations of engineering structures and technical objects in augmented reality.

We offer activity "Technical Structures in AR: Engineering Solutions". Its objective is to develop engineering students' speaking skills and technical thinking through creating presentations of engineering structures in augmented reality.

Materials: 3DBear AR app, smartphones or tablets, internet connection, engineering vocabulary handouts.

Procedure:

Explain to students that they will create a technical presentation of an engineering structure in AR. This could be a bridge, skyscraper, industrial facility, or another technical object available in the 3DBear library. Provide

essential technical vocabulary and professional language for describing structural elements, construction materials, technical specifications, building processes, and safety measures.

Demonstrate how to use 3DBear to create AR models of engineering structures. Show how to place objects, adjust their size, and add supplementary elements in the augmented reality space. Give students time to develop their AR scenes and prepare their technical presentations.

Students present their AR projects to the class, describing structural features, explaining material choices, analyzing design benefits, and discussing potential construction challenges. Their peers can ask technical questions, suggest alternative solutions, and discuss practical implementation aspects.

Assessment: Student evaluation is based on their technical accuracy, proper use of engineering terminology, quality of AR model presentation, and ability to engage in professional discussions and answer technical questions.

This activity helps engineering students develop professional communication skills in English within their field of expertise while learning to present technical solutions and participate in professional discussions. The AR technology creates an immersive environment that helps better visualize and understand technical concepts, making the learning process more engaging and practical. Through augmented reality, students can observe the application of technical vocabulary in authentic real-world contexts, improving their understanding and retention of professional language.

The task can be adapted for various engineering specialties by changing the type of structures or objects for presentation – mechanical systems for mechanical engineers, electrical systems for electrical engineers, or environmental facilities for environmental engineers. The immersive features of the app create an engaging educational environment, capture students' attention, and contribute to a more interactive learning process and better motivation.

Our practical experience has shown that AR can be used to enhance activities that promote interaction and negotiation, fostering students' ability to become confident language users and create personalized learning experiences for each student. Teachers can create AR content that meets the needs and interests of individual students, which can help them learn more effectively and stay motivated. For engineering students, AR provides unique opportunities to explore technical objects and structures in their professional context, making language learning more relevant and meaningful.

In addition to the listed options, AR can engage multiple senses in the learning process, which can help students retain information more effectively. For example, students can use AR to see, hear, and interact with English-language content related to their engineering field, which can help them learn faster and more easily.

AR can include audio cues that provide additional information or enhance the overall experience. This can include technical specifications, operational procedures, or professional explanations that provide additional context and understanding of engineering concepts.

Among AR applications, engineering students can benefit from Google AR viewer, which brings technical objects and structures into your classroom and allows teachers to create interactive tasks that encourage discussion and group work. The AR app is an excellent way to explore engineering structures and technical objects up close, with features such as scaling, rotating, and moving 3D models, as well as the ability for students to learn technical specifications and engineering principles.

Here's a classroom activity using Google AR viewer: "Engineering Structures and Systems in AR"

Objective: Create an engaging interactive AR project where each group analyzes and presents a technical object or engineering structure, using augmented reality to better demonstrate technical principles and specifications.

Instructions:

Each group selects a specific technical object or structure available in Google AR (such as engines, industrial machinery, or architectural structures). The task includes learning relevant technical vocabulary and engineering principles to understand and convey the technical context.

Each group develops a technical presentation, studies the features of Google AR viewer, and uses it to demonstrate their chosen object's key engineering aspects.

Each group presents their analysis in class, using Google AR viewer to showcase their technical objects and deliver professional explanations of engineering principles.

This task promotes the development of technical vocabulary, analytical thinking, and the ability to use AR technology for better understanding of engineering concepts. This activity not only improves technical presentation skills but also provides a unique opportunity to combine foreign language learning, technology, engineering principles, and the development of soft skills, particularly teamwork abilities.

All the mentioned platforms provide students with necessary tools for collaboration and creation of engaging AR presentations. Undoubtedly, each tool has its pros and cons. Among the disadvantages, we can note technical limitations and restrictions of features in the free segment of applications, but even under such conditions, the use of augmented reality in English language classes helps to increase learning effectiveness and motivate students to learn the language in their professional context.

The survey results revealed significant positive responses to AR implementation in English language learning:

87.5% of students reported increased engagement in learning activities

83% noted higher motivation to participate in class discussions

91% found technical vocabulary easier to remember when presented through AR

79% felt more confident discussing engineering topics in English

85% appreciated the practical application of language in their professional context

76% reported that AR activities helped them better understand technical concepts while learning English

Students particularly emphasized that AR technology allowed them to:

- visualize complex technical objects while learning related terminology;
- practice professional communication in a more engaging environment;
- better understand the practical application of English in their future careers;
- feel more confident when presenting technical information in English.

In the open-ended responses, students noted that AR integration provided a fresh perspective on language learning, making it more relevant to their professional interests. One student commented, "Seeing the engineering structures in 3D while learning English terminology made the connection between language and professional practice much clearer."

These findings align with broader research in the field. For instance, Ryani and others' [2] study of 127 engineering students showed similar positive outcomes, with significantly improved retention rates in technical vocabulary acquisition through AR applications. Bano and others [9] also demonstrated how AR environments effectively develop both technical and linguistic competencies through simulated workplace scenarios.

Our results particularly resonate with Liu and others [5] findings, which reported marked improvements in confidence levels and mastery of professional terminology among engineering students using AR-enhanced learning methods. Their study showed a 34% better retention rate in engineering vocabulary compared to traditional approaches, similar to our observations of improved technical vocabulary retention.

The integration of AR technology in ESP instruction for engineering students has shown consistent positive outcomes across various studies. Hung and others, Karacan and Akoğlu, Tsai [3], [18], [19] research supported our findings, particularly regarding the effectiveness of AR in creating immersive learning environments that enhance both language acquisition and technical understanding.

These combined results suggest that AR implementation in English language instruction for engineering students not only enhances engagement and motivation but also provides a more effective platform for developing professional communication skills. The technology bridges the gap between theoretical language learning and practical application in engineering contexts, making it a valuable tool for ESP instruction.

IV. CONCLUSIONS

The integration of AR technology in engineering English language education represents a transformative approach to professional communication skill development. Our research, conducted with second-year engineering students from Berdyansk and Vinnytsia universities, reveals the profound potential of AR in creating immersive, engaging learning experiences that go far beyond traditional language instruction methods.

The technology offers a unique bridge between theoretical language learning and practical professional communication, allowing students to visualize complex technical concepts while simultaneously developing their English language skills. Through carefully designed AR activities, students demonstrated remarkable improvements in their ability to discuss technical subjects, present engineering solutions, and use specialized vocabulary with increased confidence.

The findings echo broader research in the field, highlighting AR's capacity to transform language learning from a passive, classroom-bound activity to an interactive, context-rich experience. Engineering students no longer simply memorize technical terms; they now engage with them in virtual yet realistic scenarios that mirror actual professional environments. This approach not only enhances language retention but also prepares students for the increasingly technology-driven communication demands of modern engineering professions.

However, the implementation of AR is not without challenges. Educators must carefully balance technological innovation with pedagogical objectives, ensuring that the AR tools serve the learning goals rather than becoming a distraction. The limited availability of specialized content, potential technical complications and the need for continuous adaptation require a thoughtful and strategic approach to integration.

The survey results were particularly encouraging, with over 85% of participants reporting increased motivation and engagement. Students appreciated how AR allowed them to see language as a practical tool for professional communication rather than an abstract academic subject. The ability to manipulate 3D models of engineering structures, explain technical processes, and present complex information in English created a more meaningful and memorable learning experience.

Future research directions are promising, with opportunities to develop more specialized AR content for different engineering disciplines, create more

sophisticated assessment methods, and explore the long-term impact of this technology on professional language development. As Industry 4.0 continues to evolve, the intersection of language learning and augmented reality will likely become increasingly important.

Ultimately, the research suggests that AR is not just a technological novelty but a powerful pedagogical tool that can revolutionize how engineering students approach language learning. By creating immersive, interactive environments that connect language to real-world professional contexts, educators can develop more confident, competent, and technologically adept communication professionals.

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History at School – a Prerequisite for Understanding Engineering

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Abstract— The study of young people's knowledge of history and ways of learning is relevant because there is currently a subject "History and Social Studies I", where such subjects as economics, politics, social studies, geography and history must be taught at the same time. This is the year when the subject "History I" will be separated from it in the autumn, while the others will continue to remain combined. The idea of teaching a combined subject was presented in 2017 as part of the school reform "School 2030". Understanding the history of technological discovery is important in absolutely every industry. In the past, this task was partially fulfilled by the history subject in the school. This article will analyze the acquisition of historical knowledge in schools. The aim of the research is to find out what secondary school students know about history in the 20th-century context, as well as the ability to see regularities in relation to European and world events. 20th century the middle and the end are chosen because it is a hot topic these days in connection with the war in Europe and the flow of various information / misinformation. In this study, the in-depth interview method was used, when the most active leading experts in the history of the Latvian state – the chairman of the Association of History and Social Science Teachers, the most active members of the association in society, one of whom is also a historian, who is also the author of several history textbooks and a history specialist of the State Education Development Agency – were asked about issues of Latvian history. This study would serve as a basis for further work by surveying both teachers and high school students. One of the main conclusions of the study is that the pupils learn alarmingly little, especially about the 20th century events, especially the last third of the century. The number of hours allocated for this is often made up of reviews, which unfortunately do not look at the issues of technological development at all, when compared to the time before the reform. It should be noted that often the combined subject is taught only by a specialist in one field, who may

also be a political scientist or a social science specialist, paying less attention to other subjects accordingly.

Keywords—education, knowledge of history, history of technology.

INTRODUCTION

On September 25, 2017, the document "Education for Modern Competence: a Description of the Curriculum and Approach" [1] was submitted for public consultation in Latvia, which actually started an ambitious school reform – School 2030, the aim of which was to improve high school students' knowledge with the help of new teaching methods, i.e. with the 'competency approach' based on the belief that pupils should be able to significantly better connect existing knowledge across in different learning areas, i.e. must be able to make inter-subject connections. Although it was officially possible to express proposals and evaluations about this project on the state website for four months, it is not clear to the author from the VISIC (National Education Content Center) materials what the real involvement of teachers was in discussing the project during this time period. Although many meetings with educators were organized, the project implementers were only able to argue the necessity of the new reform among teachers very conditionally.

The official justification states that "the creators of the content have relied on the Latvian Sustainable Development Strategy "Latvija2030", which stipulates that education should be of high quality, accessible throughout life and oriented towards creativity in order to respond to the challenges of global competition and demographics." [2] As a result of the reform, school programs and teaching approaches were also changed.

However, the reform was also accompanied by extensive debates, first among teachers, about the new requirements and the insufficient explanation from the implementers of SKOLA 2030, because in all subjects the

Online ISSN 2256-070X

<https://doi.org/10.17770/etr2025vol3.8531>

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teachers were not sufficiently informed about the goals to be achieved, and proposed teaching materials – textbooks and other materials – were not prepared. This was also the case with regard to the subject of history, which in previous years was created in primary school as "Latvian History" and "World History", and in secondary school as "Latvian and World History". In these subjects, the history of technology also had a certain role, because the development, starting from the 19th century, significantly influenced the course of history.

The consequences of the reform were visible at every step, in the form of so-called study baskets, where the pupil had to choose one of the study directions when starting studies in secondary school. As a result, the subject "History and Social Studies I" was created, where earlier subjects such as economics, history, geography, social studies, cultural history, and politics are to be taught at the same time. [3]

In the opinion of the author, whether attention was paid to history at all depends solely on the personal desire and ability of the teacher of the relevant school subject to include the entire learning complex homogeneously in the learning process. A serious obstacle was that this subject was taught by a wide variety of teachers who were not prepared for this kind of work, but additionally, as the author believes, history was often included less by teachers because they regarded other sections as "more important" – for example, economics or politics. Understanding the problems of the situation, in some schools the new subject was still divided into several parts, usually economics and the other parts, which were taught by specialists of the former subjects.

After completing this combined subject, the pupils could choose which subject he would study in depth. As a result, in the opinion of the author, there were not many pupils who chose to study "History II" in depth. And this is a big problem, because without knowing history, we "don't understand today" [4], as the professor of history Ēriks Jēkabsons has pointed out, meaning wider developments. Unfortunately, it has not been possible to find out exactly how many pupils in Latvia have chosen to study "History II" in depth. Judging by the number of pupils who have chosen to take the "History II" exam in the last two years, the number of such pupils is not large. At the same time, it should be pointed out that in changing conditions with so many changes, even teachers do not want to force their pupils to take an exam in history when the conditions of the exam are not known or fully understood.

It should be emphasized that without knowledge of history it is impossible to understand the regularities of many things. This undoubtedly applies to the history of the development of various, even the most modern, technologies. All "leaps" in technological development have a basis in history, and just like every field of technology, historical studies have been devoted, incl. also in Latvia, for example, the history of the State Electrotechnical Factory (VEF), to which even a museum is dedicated [5], the history of telecommunications [6] or the history of industry [7], etc. These studies create a chain

of regularities needed everywhere, but especially in STEM subjects. The statement that, for example, extensive knowledge in natural sciences helps to achieve success in engineering sciences is also historically well-founded. History plays a significant role in building knowledge about this.

Unfortunately, after the school reform, one of its actual results is that the history exam was abolished in elementary schools, which in practice meant that many elementary school pupils were not able to concentrate and focus their knowledge anyway. This problem has been pointed out by many high school teachers in mutual conversations both at the summer days of History and Social Studies teachers and at the conferences that are held every year in January. In addition to this problem, there are also consequences of the remote learning process during Covid-19, which has certainly not benefited young people in acquiring knowledge. [8]

These factors also undoubtedly affect high school history classes, where it is first necessary to be able to recover the delayed learning process in the acquisition of basic knowledge. This, in turn, prevents focusing on in-depth knowledge acquisition and competence acquisition. As a result, young people's knowledge is increasingly narrowing and decreasing, which university lecturers have already noticed. Undoubtedly, the war started by Russia in Ukraine also contributes to the overall understanding of the problem. [9]

II. MATERIALS AND METHODS

The study basically uses the in-depth survey method with open-ended questions, where the respondent had the opportunity to express himself in more detail. Since the survey was conducted in person, interview elements were also used during it, asking the respondents some additional questions.

The length of the survey was planned to be thirty minutes, but in practice it lasted a little more than forty minutes. At the beginning of the study, a descriptive method was used to outline the research field and general issues as precisely as possible. During the study, special attention was paid to school programs. The study does not include, but considers, the study of the content of school history textbooks that relate to the topic under study.

III. RESULTS AND DISCUSSION

All the above factors prompted the author to conduct in-depth research to find out the real situation. For this purpose, an in-depth focused survey was chosen – conversations with history specialists in Latvia who not only teach history in one or a couple of schools, but for various reasons have worked on solving issues related to history teaching at the national level or even internationally. Four well-known specialists in the field of history recognized in schools in Latvia were interviewed - Baiba Atmane, currently the leading specialist of the State Education Development Agency (VIAA) at the Ministry of Culture of Latvia; Roberts Kipurs, the chairman of the Society of History and Social Studies Teachers; Jānis

Arājs, a history teacher of Riga State 2nd Gymnasium and a socially active member of VSSB; and Valdis Klišāns, who is not only a history teacher at Teika Secondary School, but also the author of many history textbooks.

Research on the historical knowledge and learning methods of young people in 2025 is relevant for several reasons. First of all, this is the year in which, starting in September, the subject "History I" will be introduced in schools. Secondly, it is necessary to identify the current situation in history learning before/after the changes that started in 2017, within the School 2030 project. The aim of the study is to understand what, according to specialists, Latvian secondary schools youth really know about the history of the 20th century, in the context of the occupation of Latvia, and what is the basis for this situation is. Also, one of the tasks is to understand whether the pupils are able to connect the existing knowledge with the events of European history. According to the information available to the author, different studies of this type have been conducted in the past, [10] but currently there are none.

Latvian 20th century the development of the second half (the period of the Soviet and Nazi German occupations of Latvia) was chosen because nowadays it is a topical topic in connection with the war in Ukraine and the flow of various information (or disinformation) about issues of Latvian history. Among other things, a very important aspect of this stream is precisely the history of the development of technology. Thus, the study of the issue is closely related to media-literacy. It is also important to find out the family, internet environment, etc. impact on the formation of understanding of historical issues. Due to the proposed focus, the Latvian Occupation Museum is also interested in learning the results of the study.

The study is also expected to be expanded by conducting surveys among both teachers and pupils in September this year. In the in-depth and focused survey, specialists were asked seven basic questions, but specialists could also give more extensive answers. The interview time was supposed to be half an hour, but in reality, it was at least 40 minutes.

The questions were put to the experts, allowing them to speak freely and expand if they felt it was necessary. The questions are made broad so that the experts can expand their thoughts. The responses were audio-recorded for later analysis. Since the responses were extensive, they have been used in this study, reflecting only the main thoughts and ideas. The interviewed specialists answered all the questions, however, the answers varied both in terms of volume and depth.

1. question. What is the pupils' knowledge about Latvia's 20th century. middle/end period and whether the pupils are able to connect this knowledge with the European 20th century. historical events?

The first question was intended to be a question of ascertaining the general situation, where the experts also gave the most comprehensive answers. Three out of four experts indicated that the lack of prior knowledge of pupils

in understanding various historical events has a major impact. They connected this with the fact that in elementary school in the 20th century history, including periods of occupation, is the last topic that is looked at, and often teachers in the 9th grade simply—"don't manage" to consider all the topics in a sufficient amount, sometimes only mentioning the events as such, but not creating an understanding of them in any way. According to R. K., such a situation has "if not killed, then devalued" the interest in history in young people. According to him, under such conditions, it is difficult for pupils to connect the events of Latvian history with European history, which was also agreed by other experts.

B. A. additionally stated that before the school reform SKOLA 2030, the amount of history lessons in both primary and secondary schools was significantly larger. As an example, the Second World War was mentioned, which used to be devoted to at least four hours of study in elementary school, whereas now it is only 20 minutes. In addition, the absence of a history exam does not force young people to make a wider study of history. This missed learning process has to be recovered in high school. On the other hand, V. K. emphasized that it was precisely in the 20th century historical processes are of interest to the pupils, but he also noticed that the opinion of the pupils has remained too vague in recent years and the knowledge of the pupils has become weaker. J. A. also agrees with the last statement, which, in turn, highlighted that by emphasizing skills, we have lost the pupils' real knowledge, without which understanding cannot be formed. As an argument, the situation was invoked when at the national level, pupils have considerable difficulty in grouping events in historical order, which in earlier years was one of the easiest tasks, where students "collected" the most points.

2. question. How does the knowledge learned at school fit in with the knowledge gained in the family or society? Is the pupils' nationality important and does it affect the work in the classroom?

When answering the second question about the acceptance of the knowledge to be learned among pupils, especially those pupils whose native language is not Latvian, the answers were given in a very thoughtful way. The answers varied because, for example, J. A. stated that he works in a school where mostly all are Latvians, and the existing non-Latvian pupils are well integrated. Also V. K. stated that the situation at the school where he teaches is calm, and the events of recent years can be safely discussed, including war in Ukraine. However, at the same time, there are pupils for whom the world's turn against Russia creates internal psychological stress.

At the same time, V. K. but emphasized that in 2022, he heard from teachers in various teacher courses that some history teachers chose not to talk about the war in Ukraine in order to avoid a potential conflict. In the lessons, the teachers have emphasized that "we are for peace", without indicating in any way what has destroyed this peace. B. A. also indicated that special materials have been prepared for

learning the history of Latvia in minority classes, which would also show the belonging of these groups of people to the history of Latvia.

Although B. A. stated that there were no conflicts, however, it was felt that the non-Latvian pupils agreed only externally. B. A. stressed with concern that the practice of not talking about problems, incl. about the war on the territory of Ukraine, is a bad practice, because in this way we will not even know what the student really thinks, even though these same pupils were born in Latvia after 2004 – that is, in the European Union. B. A. especially highlighted that Latvia's desire to prepare the best possible natural science specialists does not lead to citizens who feel their belonging to the Latvian state. In addition, young people who are well prepared in the field of natural sciences also leave Latvia more easily after their studies, which is fundamentally wrong. Finally, R. K. admitted that after 2022, the topic of war is completely uncomfortable, because even within the same family there are cases when opinions do not coincide.

3. question. What is the pupils' knowledge about the period of occupation of Nazi Germany (1941-1945)? Which topic are students most knowledgeable about, why do you think that is? What does it relate to?

In answer to the question about the amount of knowledge during the occupation period of Nazi Germany, all respondents agreed that this period is relatively still able to appeal to young people, but here too the knowledge of young people is only about certain topics. According to R. K., even the holocaust topic is gradually turning into a topic that pupils know less and are less interested in, even though the situation was different 10 years ago. It is similar with other topics such as the so-called Latvian Legion, etc.

This opinion was partly agreed with by V. K., who pointed out that the pupils had heard the most about the topic of the Holocaust, because a lot of funds were invested in it in various projects. Undoubtedly, it is also an emotionally heavy topic that sticks in memory. J. A. outlined the situation, clearly highlighting that general knowledge about the time of German occupation is very weak, where, for example, there is no understanding of the economic policy of Nazi Germany. This opinion was joined by B. A., who emphasized that it is possible to expand knowledge and there would be interest, but it requires a lot of teacher's investment.

V. K. highlighted the impact of cultural phenomena, such as the impact of new films released, which affect society only for some time - about five years. According to the author, one must agree with this idea, because the influence of films, series and documentaries is undeniable in various fields, including in medicine, engineering, etc.

4. question. What is the pupils knowledge about the occupation of 1940–1941 and post-war occupied Latvia? Which topics are students most knowledgeable about, why do you think that is? What does it relate to?

Specialists answered the question about pupils' knowledge about the Soviet era quite similarly, emphasizing common trends in knowledge. On the one hand, all the Soviet times, which have been 46 years, being perceived as one common event in which there are really

no periods and changes. There are still various myths that teachers have to dispel. For example, the myth that it was not possible to speak Latvian during this period, or that there was a famine during the Soviet occupation, or vice versa - there were good times, when everyone had a job, etc.

V.K. pointed out that pupils find the period of Soviet occupation interesting in its own way as a "kingdom of crooked mirrors", where many things are not as they initially appear. As an example, V.K. invoked the one-party system, where pupils automatically associate it with the party system when they hear the words "political party". R. K. pointed out that there are students who know a relatively much about Soviet times, but mainly because of deportations, when relatives were deported. On the other hand, pupils from Russian-speaking families basically know the general "truths" that everything was in order during the Soviet era, factories worked and generally lived well.

Although certain symbols of the ideology are recognized as pioneers, emblems, there is no longer a deeper understanding of what this ideology did and why it was like that. Worst case scenario, according to J. A., is the fact that young people perceive what is written directly, and the hidden thoughts contained are difficult for pupils to recognize. In addition, pupils actually have no knowledge of the economic policy and economic development of the USSR.

5. question. What are the key concepts when teaching about the time(s) of occupation in schools? How many such concepts are there?

When answering the question about the concepts, the experts all agreed that the existing set of materials is completely sufficient, as long as it is used wisely. As an example, the collection of terms used in history was mentioned, but the most serious problem was the lack of familiarity with various abbreviations, which also causes problems for adults.

6. question. What is the importance of modern technologies in the learning process and the real possibilities of using them during lessons and for tasks outside them?

On this issue, the opinions of experts differed quite significantly, putting emphasis. V. K. pointed out the various possibilities and emphasized that they are mainly important for the teacher, not the pupil. The use of opportunities is wide, however, not all types have proven themselves over a long period of time. There have also been projects that have not been able to prove themselves over the years. At the end of the 1990s video lectures of university lecturers were made, nowadays they are no longer really usable due to the volume.

Regarding artificial intelligence, experts believed that it is not capable of giving full-fledged answers in the history of Latvia, at least for now. In addition, pupils are led to believe that this is some kind of "intelligence", not realizing that it is just programmed responses that someone has programmed. Also, all the respondents agreed that there is technical equipment – a projector or a TV screen – for visualization purposes. Only J. A. pointed out that the old methods with the blackboard as an

additional option also work well. Absolutely all experts pointed out the lack of a textbook in the learning process. On the other hand, V. K. emphasized the huge importance of technology in working with foreign students, translating content and comparing situations.

7.question. What are the elements that you think are missing or could be improved? How to do it? How do pupils see it?

Unexpectedly for the author, experts analyzed this issue more thoroughly than expected. Opinions were divided when R. K. stated that there must be textbooks and methodical instructions. V. K. more emphasis was placed on thematically organized photo and video collections, which the teacher could freely use, for example, when talking about the development of the construction field or railway infrastructure, which is important nowadays due to the construction of Rail Baltica.

On the other hand, J. A. rightly pointed out that in his case all the most important museums are within reach and there is no need to look for new approaches in a situation where the old methods work well. However, what has been said applies only to teachers of schools in the center of Riga. Also B. A. emphasized the greater importance of extracurricular activities, analyzing and comparing the offers of different museums. All those surveyed indicated that with such a small number of school hours, many museums such as the Motor Museum, Art Nouveau Museum, etc. visit is not possible at all.

CONCLUSIONS

In secondary schools, teachers often have to work on improving the general knowledge level of students, as a result of which there is no time left to delve into specific areas. This is also related to the lack of a history final exam in primary schools.

Due to the inertia of some teachers, working with the earlier chronological approach to historical processes, they present more the events of the earlier centuries, devoting less attention to the 20th century. second-hand history questions. This also means such an important topic as industrial development as a whole, but separately railway, energy, etc. misunderstanding of aspects, due to lack of knowledge. One of the explanations for this is the lack of textbooks. As a result, pupils have very fragmented knowledge.

In the conditions of the lack of textbooks, even though there is a variety of different materials in the modern world, teachers still must invest a huge amount of work to prepare the thematic development of individual lessons, etc.

In schools, the combined subject "History and Social Sciences I" is taught by teachers who have not been prepared for it, as a result of which the set of knowledge acquired by students may differ significantly in each school.

The teachers also found that the mass of actual knowledge has significantly decreased both due to the priorities of the school reform SCHOOL 2030 and due to the sum total of other circumstances.

Finally, it must be concluded that the combined subject "History and Social Studies I" no longer teaches about the development of technology and its importance in practice. Although some teachers pay attention to it, it is no longer a requirement that everyone must follow, unlike the time before the reform.

As a result of the research, the author has come up with several proposals, which have already been presented to the leadership of the Association of History and Social Science Teachers. One of the proposals is to obtain more accurate data from the Ministry of Culture on the number of history teachers. As a second proposal, when creating the curriculum, prepare specific proposals so that the history of technology is also included in the program, which can also be done by attracting museum specialists to schools. Such a practice exists, for example, at the Museum of the Occupation of Latvia. Finally, to address history teachers in a more targeted manner in order to create common guidelines for the creation of priorities for the history subject.

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Remote Study Work Challenges and the New Model in Post-COVID and Pre-AI Era

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Abstract – The aim of this research is to understand the complexity of student's and teaching staff behavior and experience in times when study work in real auditoriums is mixed with remote learning. Since 2020, the author has conducted an annual survey of several hundred students of computer science at the University of Latvia and Riga Technical University for 5 years about the possibilities, usefulness, problems, satisfaction, benefits and visions of remote and distance learning. The study shows the dynamics of changes in student opinions and technical capabilities over these 5 years, including COVID and post-COVID periods. The author offers a model of productive study work that includes mixed methods, Moodle e-course management and advanced technologies, increasing student responsibility in remote work in an environment where some technical problems and artificial intelligence are present, to achieve the best possible result.

Keywords – e-course management, interactive learning, higher education, remote learning, online learning, mixed methods, Moodle.

I. INTRODUCTION

The study process is part of the social, economic etc. life of society, so global changes are always reflected in it. E-learning is more complex than we usually see when viewed from the student or even the instructor's point of view. We need to look as broadly and deeply as possible at the links between e-learning in different directions. In the Khan model the eight dimensions of the e-learning framework are: institutional, pedagogical, technological, interface design, evaluation, management, resource support, and ethics [1]. The COVID-19 pandemic affected learning process of more than 1.6 billion students and youth worldwide, and some gains already made towards the goals of the 2030 Education Agenda were lost [2]. However, we can say with great positivism that e-study and remote learning saved the education system, maintaining its continuous functioning. It is likely that the importance of remote learning will only increase in the

future, so it is worth continuing to explore opportunities for improving distance learning and using blended methods in new layers of next models.

The origins of remote learning can be traced back to the 1960s as distance learning, when paper letter correspondence courses began to be introduced in the United Kingdom Open University. In 1970s Otto Peters described distance education as an industrialized form of education theory as principles of 1960s industrialization reflects in the proposition that distance education can be an industrialized form of teaching and learning. Peters root his theory in technology and economics. Then new theories related to pedagogy appeared from various authors. After the triumph of PCs in the 80s, paper correspondence turned into email correspondence in the end of 80s and 90s, but the 21st century began with web-based learning solutions [3]. In 1999, Moodle's founder and lead developer Martin Dougiamas in Australia introduced a new type of open source Learning Management System (LMS) – MOODLE, and in 2002 Moodle 1.0 was released [4]. In the last decades, MOODLE is the most popular and probably the best LMS for distance and remote learning, the current version is MOODLE 4.5, also used as the main LMS in Latvian universities, also next step of comprehensive modernization of study solutions is planned in the next five years.

With distance learning the author understands the system of teaching and learning where there is geographical distance between the teacher and the learner and technology and media are used for communication between them. Typically, distance learning takes place according to special programs, but remote learning is the transfer of face-to-face learning partially or temporarily completely in a remote/ online mode. Therefore, during COVID, we talk more about remote learning, but before and after that – more about blended/ mixed methods of learning.

Online ISSN 2256-070X

<https://doi.org/10.17770/etr2025vol3.8547>

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The aim of this research is to understand the complexity of student's and teaching staff behaviour and experience in times when study work in real auditoriums is mixed with remote learning. The author offers a model of productive study work that includes mixed methods, Moodle e-course management and advanced technologies, increasing student responsibility in remote work.

II. MATERIALS AND METHODS

The experimental part of the study consists of surveys of IT students over a 5-year period at two Latvian universities. However, the results of the study are published here for the first time.

The Latvian education system was relatively well-prepared for the 2019 pandemic, as Moodle e-learning had been implemented in all Latvian universities, and the University of Latvia and Riga Technical University provided schools with the opportunity to host their e-courses on university servers. But the implementation of Zoom or Teams was easy. It so happened that already in 2013, using the opportunities provided by ESF projects, we created a still-up-to-date MOODLE e-course designer manual [5] and a tutorial on creating educational institutions' Moodle server [6]. Therefore, after more than 10 years of using LMS in universities and 5 in many schools, the transition to remote work in the 2019/2020 academic year was not a shock to either teachers or students, and we were able to continue our studies while simultaneously thinking about finding ways to improve the few problems we encountered.

Since 2020, for 5 years the author has conducted an annual survey in Operating systems course last lectures of 1174 students from the Latvian stream (by years: 214 in 2024/2025+ 285+ 233+ 264+ 179 in 2020/2021) of computer science at the University of Latvia (2020/21) and Riga Technical University (next 4 years) about the possibilities, usefulness, problems, satisfaction, benefits and visions of distance and remote learning. The study shows the dynamics of changes in student opinions, technical capabilities and some permanent problems over these 5 years, including COVID and post-COVID periods. Students were asked to respond not only to the courses taught by the research author, but to the entire study process as a whole.

Respondents were asked 12 self-rating questions, of which 10 questions used a 5-point Likert's scale, where answers are coded as "yes" = 1.00 point, "more yes than no" = 0.75, "neutral" = 0.50, "more no than yes" = 0.25 and "no" = 0.05 (no answer = 0), but one question had a multiple choice of 11 answers and one had a free text answer. The numerical results of the survey (average points of responses) are given in Table 1.

Usually, survey results indicate percentages, but here the author introduces a positivity coefficient because I want to study positive attitudes. Therefore, the higher the average positivity coefficient of Likert scale responses, the more positive the students' attitudes; the exception is the negative question J9, the results of which are given in percentages. However, for clarity, a link with percentages

can be indicated, for example, in the 20/21 academic year study, the positivity coefficient for question 6 (hereinafter Q6) is 0.978, but the Likert scale responses were distributed as yes = 91.06%, then 7.82%, 0.56%, 0% and no = 0%. Reliability for the total items is not less than $\alpha = 0.95$.

Full text of the questions asked in the survey: Question 1 or Q1 – Is the use of the e-study environment MOODLE in remote learning/ studies useful (materials, quizzes, uploading of work, assessments, communication, etc.)? Q2 – Is the use of remote conference environments Zoom, Teams or others for remote lectures useful? Q3 – Would it be important for you to have the same login name in e-study and Teams or Zoom to enter authentication data only once? Q4 – Is it important for you that the IT tools and environments used are also available on a mobile phone? Q5 – Is it enough if lecture video recordings are kept for 30 days? Q6 – Is it useful if approximately 40... 50 min. long topic overview videos are given that are kept for a long time (MS Stream, Zoom Cloud, YouTube)? Q7 – Did you find it useful to use short (1-5 questions) quiz at the end of each lecture to register attendance? Q8 – Is it worth supplementing the remote study process with other tools (e.g. Skype, WhatsApp, HotPotatoes, group work environments, avatar 3D games, etc.)? Q9 – Did you have technical problems participating in remote lectures, practicals, consultations, meaning not only the Operating Systems course (computer performance, internet bandwidth and stability, webcam, etc.)? Q10 – Would you be okay if all communication (receiving materials and assignments, sending work) took place via email? Q11 – Are you ready to work remotely for at least half of the semester next semester without any significant problems (do not think about a specific study course, lecturer, but in general)? Q12 – If you wish, write down what else is important, what should be added about the process of remote studies.

III. RESULTS AND DISCUSSION

TABLE 1. SURVEY QUESTIONS AND RESULTS BY YEAR

Nr	Question	20/21	21/22	22/23	23/24	24/25
1	MOODLE is useful	0.90	0.87	0.86	0.88	0.85
2	Zoom, Teams are useful	0.93	0.95	0.95	0.87	0.88
3	Single Sign-on	0.72	0.71	0.77	0.67	0.65
4	Mobile phones support	0.67	0.66	0.77	0.77	0.78
5	Enough keep the videos for 30 days	0.51	0.50	0.62	0.57	0.49
6	Topic overview videos are useful	0.98	0.95	0.95	0.96	0.94
7	Usefulness of short attendance tests	0.83	0.79	0.80	0.79	0.80
8	Need more tools	0.50	0.44	0.51	0.49	0.49
9	There were technical problems	0.30	0.14	0.23	0.18	0.15
10	If everything is in the email	0.42	0.43	0.54	0.42	0.45
11	Ready for half a semester Remotely?	0.87	0.89	0.90	0.77	0.85

A. Primary survey results

1. As can be seen from Table 1, support for the main remote learning technologies remains consistently high: the average positivity coefficient all the time is about 0.85 for LMS Moodle (question Q1) and the video conferencing tools Zoom and Teams (Q2) get about 0.87, and no one has given them the lowest rating. However, support for Moodle has decreased by 5.6% in 5 years and for video conferencing tools by 5.3%, which is easy to understand as work in university classrooms has resumed. It is rather surprising that support for remote learning tools is still so high; perhaps students want to participate in lectures not only from home, but also from their workplaces, which is a relatively new motivation for introducing blended methods.

2. Usually, students do not like repressive control methods, but this time the author was pleasantly surprised by the large approximately 0.80 support for short attendance control quizzes (Q7) in the MOODLE environment (3...5 questions at the end of the lecture or a little earlier at the time of lecture). Perhaps the pandemic made students more conscious of the courses they want to learn, and proper motivation of students probably plays a role here: the author allowed with these quizzes to earn +1 point for final grade if 80% of the quizzes were completed 80% correctly (IT certification standard), and there was also a consolation prize of +0.5 for 70% to 70%, and some of the questions were repeated in the exam big quiz. It is important to note that over the past 5 years, satisfaction with lecture attendance quizzes has remained stable with a positivity coefficient of 0.8. This suggests that at least 80% of students are interested in their studies.

3. The desire to use used remote studies tools on a mobile phone/smartphone (Q4) has increased by 16.5% over the past 5 years (from 0.673 to 0.784), as well as shows an increase in the welfare of society. This shows a desire to use time effectively and study everywhere, but some students may also enjoy the opportunity to cheat on quizzes, exams from their smartphone or smartwatch; but in any case, we should support smartphones.

4. The greatest support from students (approximately 0.95) for in the e-course included approximately 40...45-minute theme overview videos (Q6) that contain the main ideas from the lectures and for the practical work of the Operating Systems course. These videos are rated the highest all the time, the decrease in positivity about them in 5 years is only 4.2%. Meanwhile, approximately half believe that videos should be available for longer than the standard 30 days (Q5) 0.5...0.6.

5. As expected, less positivity ~0.45 is about the idea all study work communicate in email (Q10) instead of Moodle. Also, less than half ~0.49 believe that more tools are needed (Q8). Maybe it's really not worth getting too carried away with external tools, because Moodle has everything essential for massive, rich e-courses: placement and grouping of materials, submission of reports, quizzes, surveys, a calendar, even a tool for virtual seminars and plagiarism check etc., the exception

is the placement of large video files (for example, over 100 MB, but it depends on the server settings), which the author published on YouTube (some as public, some as available only via the link provided in the e-course), because in Zoom and MS Teams/ Stream shared folders they were deleted every year or sooner.

6. There is no unequivocally convincing support for single sign-on authentication (0.65 in 2025), and it has been declining in 5 years by 10% (Q3). The motivation for this was not studied, perhaps there are security concerns (respondents are computer science and IT students), but perhaps it is related to the ability to save login information in the browser.

7. The most unpleasant discovery: still in 2025 at least 15% of students indicate significant technical problems in remote work (Q9); students are considered to have counted if they have at least two significant problems: insufficient computer performance, unstable or insufficient internet bandwidth, power outages (they were indicated by only 6 students and only in the first year of the survey); the disappearance of mobile Internet zones prevailing in certain places in Latvia (eastern border areas, as well as the 1st floors of Riga multi-storey buildings and some places in rural regions). It is positive that five years ago 29.61% of students had two big problems together, but in the last 3 years the situation has improved, and this level has remained constant at around 15%, which is a lot anyway. Minor problems were considered to be the absence of a webcam, microphone, insufficient performance of the student's computer for virtual machines, or the problem having occurred only once per semester.

8. There is reason to think more about blended study methods, as the positivity coefficient ~0.85 indicates that they are ready and willing to do half of their study work remotely (Q11). The coefficient has decreased by only 2.7%, which is close to the measurement errors. This also indicates that we are on the right path in the field of e-learning and remote studies.

B. The brilliance and bane of artificial intelligence in universities

The role of artificial intelligence (AI) in LMS could be the subject of separate studies and have a great future, so here the author will limit himself to observations from practice. The positive side is that AI allows for the rapid processing of large amounts of data, the generation of presentations, the assessment of students' works, for generating quizzes/tests, the detection of plagiarism in student work, face control in exams, etc.

However, the negative manifestations of AI are alarming. For example, all students who were caught using ChatGPT during an exam quiz later knew an absolute zero in the required oral answer, unlike the others. This raises concerns about the effectiveness of the above-mentioned lecture attendance quizzes for learning, because, together with AI they will only provide a record of attendance.

On the one hand, the author agrees that nothing will prevent a student who does not want to learn from not learning, so repressive methods must be developed to control real knowledge. However, it is important not to overdo them, e.g. international students often use AI-powered translators to get English text from their native language; such a translation sometimes looks like it was generated by AI, but they are not. It is important not to falsely penalize them.

In the discussion about what knowledge, skills, abilities, the author would like to add that it is what has lasting value in the student's mind. Imagine that the electricity is powered off for 3 months, then what you will be able to do, solve without a computer, phone and internet will also be what made studying worth it. The concept of competencies mentioned in the model can be understood as knowledge, skills, abilities with a creative application layer.

C. Another next model of remote learning

Before offering a new vision, it is useful to look back at the best existing remote study models. More popular theories and frameworks for online education are discussed in Picciano A. G. book "Theories and Frameworks for Online Education: Seeking an Integrated Model". From here, Bloom's taxonomy (1956) is based on six key elements. They can be drawn in a pyramid, then from the bottom: remembering, understanding, applying, analyzing, evaluating, creating. As next level, Robert Gagne developed another taxonomy that built on Bloom's and became the basis for cognitive instructional design; Gagne's nine events of instruction: gain attention, describe the goal, stimulate prior knowledge, present the material to be learned, provide guidance for learning, elicit performance, provide feedback, assess performance, enhance retention and transfer [7].

The old models were created by excellent educators and psychologists, but today the environment has changed, much is determined by IT capabilities, and often new tools are created by programmers themselves, intuitively sensing what educators might need. Consequently, our efforts to organize our ideas into models must be supplemented by new realities.

Anderson's Online Learning Model is based on new IT capabilities, using Semantic Web concept and technologies, so LMS can work with three agents: teacher agent, content agent and student agent. There are different collaborations between student – content, student – teacher, student – student, teacher – content; these interactions are affordable, reusable and facilitated by active agents. Knowledge content may be interactive, and implemented for asynchronous and synchronous learning. Supported studies types in LMS can be: independent study, paced collaborative learning, community of inquiry, structured learning resources [8].

Khan's popular model describes the eight dimensions of e-learning framework are: institutional, pedagogical, technological, interface design, evaluation, management, resource support, and ethics [1]. Khan's diagram of this

venerable model is flat and all sides of the octagon are of equal size.

The author of this article believes that the number of elements needed in the next model is more complex, and it is a multidimensional, multipolar, balanced. The next model of remote learning for today and the near future the author tries to offer in Figure 1.

The model diagram proposed by the author contains 20 elements, several of which have sub-elements, but only 7 links are indicated, without which the system would not work. The remaining links connect teachers and students to all elements. These connections they will create themselves during the learning process.

Everything is connected to everything, but you can try to count how many connections you make in your daily work. The author encourages teachers, lecturers, and professors to use all the key elements of remote and distance learning mentioned in the model. At any time, we can add something else, some more external tools, but too many tools distract students from the material being learned.

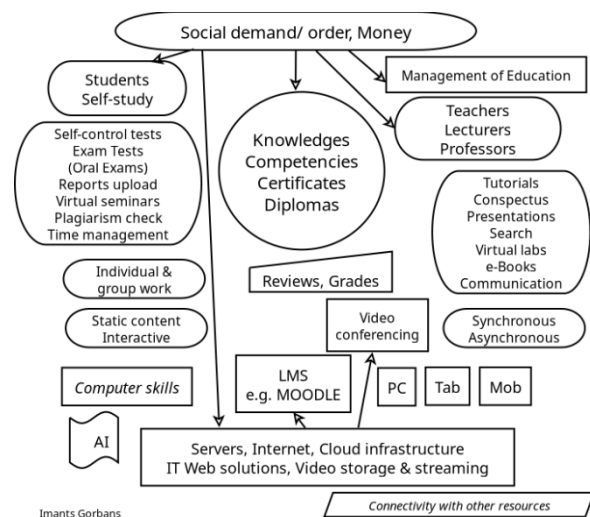


Fig. 1. The next model of remote learning for today. Imagine for yourself that students and teachers are connected with everything.

IV. CONCLUSIONS

In recent years, remote learning has developed rapidly, as remote studies were a real necessity during COVID-19. The intensive work remotely and author's survey and experience highlighted some additions to previously known models and recommendations for educational managers, professors, teachers:

a) As shown by the student survey responses, they accepts very well **self-control quizzes/tests** at the end of each lecture very positively, especially if they are also attendance registration; these quizzes should not be allowed to be taken in adaptive mode or repeated more than 1 or 2 times, so that students who did not attend the lecture cannot guess; in the fight against communication in social media and AI, only a very short quiz execution time is useful, maximum 1 minute per long question;

b) It is not useful to keep video recordings of lectures for a long time or to create them at all, but students appreciate highly shorter **videos of topic reviews** very positively, which makes sense to keep them for a long time;

c) Student collaboration is also possible in the MOODLE environment, for example, **in virtual seminars**; they are useful for discussions and grading of project reports, some practical works, they can be assessed by 5...7 randomly selected students (it happens automatically in virtual seminar tool);

d) Face-to-face **lectures can be broadcast** on a video conferencing tool after COVID-19 too; it is better for students to participate in lectures remotely from home, in a coffee shop or at work, surrounded by colleagues, than not to participate at all;

e) All remote learning tools must be available not only on computers, but also on tablets and, in recent years, especially on **smartphones**;

f) **Different methods** should be mixed, including synchronous and asynchronous study, and finally, remote work is cheaper for the university;

g) It is important for the student to always **receive feedback** from the teacher, and this can only be partially replaced by artificial intelligence (AI) or old algorithms;

h) It is necessary to continue to search for useful uses of AI and methods of combating **unethical use of AI**;

i) The situation with power outages and mobile internet coverage **has improved in Latvia** over the past 5 years, and the situation is good right now;

j) The **demands of society and employers** take precedence over the wishes of students;

k) Educational institutions must decide between their **own servers and a rented cloud** environment (remembering that in the Middle Ages, the basis of feudalism was land rent for farmers, but privatization led to higher work efficiency), the optimal solution could be that organization to have a low/middle-performance server supplemented by a cloud solution;

l) Individual countries and regions may be temporarily disconnected from the global Internet, so it is important to create **systems that can work locally** – if there is no doubt about MOODLE, then local video conferencing tools can be created from e.g. <https://jitsi.org/>;

m) By introducing **positivity coefficient** in survey analysis, the author tried to emphasize that in study work it is important to direct the process with a positive attitude.

ACKNOWLEDGMENTS

The author is grateful to the students and colleagues of the IT faculties of Riga Technical University and the University of Latvia for their participation and discussions.

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Auditing Educational Quality Management Systems - Now and in the Near Future

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Abstract— The paper presents important standards that need to be considered by educational organizations when auditing their quality management systems. Traditionally, these quality management systems are based on ISO 9001, and are audited based on ISO 19011. Starting in 2018, a new standard - ISO 21001 provides requirements and guidance for the management systems of educational organizations, including universities. In 2025 all of the three standards mentioned above are undergoing changes that will affect the way educational quality management systems are developed, implemented, audited, and improved.

Keywords— *auditing, educational management system, quality management systems.*

I. INTRODUCTION

Quality management systems (QMS) have been standardized at international level by ISO, the International Organization for Standardization, since the 1980s with the publication of the ISO 9000 series of standards. The requirements for a QMS of organizations of any size and sector are specified in ISO 9001. Its current fifth edition – ISO 9001:2015 [1], was last reviewed and confirmed in 2021, but in November 2023 a decision for its revision was made. An amendment to ISO 9001:2015 was published in February 2024 and it reflects the need to adapt QMS with elements dealing with climate action changes [2].

The history of standardization of educational QMS can be traced back to the two editions of the International Workshop Agreement (IWA) “Quality management systems - Guidelines for the application of ISO 9001:2000 in education” IWA-2:2003 [3] and IWA-2:2007 [4]. Publications [5], [6] and [7] present the period preceding the publication of ISO 21001 [8].

The first standard with guidelines for auditing QMS was published in 1990 as ISO 10011. In 2002 it was replaced by ISO 19011 “Guidelines for quality and/or

environmental management systems auditing”. The wide variety of management systems caused a change in the title and applicability of its second edition ISO 19011:2011 “Guidelines for auditing management systems”. The third edition of ISO 19011 was published in July 2018 and is still valid today [9].

The purpose of this paper is to demonstrate key elements of auditing educational QMS nowadays, and to shed light onto the upcoming changes.

II. MATERIALS AND METHODS

The main method used in this paper is comparative analysis.

The first analysis is based on the comparison of the structure of ISO 9001:2015 – the basic QMS standard, and ISO 21001:2018 – the standard for educational organizations.

The second analysis is the effect of the latest edition of Annex SL, Appendix 2 “Harmonized structure for Management System Standards with guidance for use” [10] on the future revisions of ISO 9001 and ISO 21001.

The third comparative analysis is of the QMS implemented in two Bulgarian universities.

The three segments of the comparative analysis are then used as inputs to establish the auditing process and its typical documentation – audit programme, audit plan, audit questionnaire, audit report, etc. Auditing methods are presented as on-site and remote auditing as performed during the COVID-19 pandemic at the abovementioned universities.

Online ISSN 2256-070X

<https://doi.org/10.17770/etr2025vol3.8561>

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III. RESULTS AND DISCUSSION

A. Comparison of the structure of ISO 9001:2015 and ISO 21001:2018

In general, both standards share the common structure and common requirements of Annex SL. As expected, because ISO 21001 is published 3 years later than ISO 9001, it is adapted to a more recent version of Annex SL.

There are no major differences in Clause 4 “Context of the organization” and for both standards it is comprised of: 4.1 “Understanding the organization and its context”, 4.2 “Understanding the needs and expectations of interested parties”, 4.3 Determining the scope of the quality management system (QMS)/Management system for educational organizations (EOMS), and 4.4 “QMS and its processes”/EOMS.

The overall structure of Clause 5 “Leadership” is also identical for ISO 9001 and ISO 21001: 5.1 “Leadership and commitment”, 5.2 “Policy”, and 5.3 “Organizational roles, responsibilities and authorities”. The first difference is in Clause 5.1. ISO 9001 has 5.1.1 “General” and 5.1.2 “Customer focus” which is a direct reference to the first quality management principle. Even though ISO 21001 has the same name for Clause 5.1.1 “General” its content is richer than the one of ISO 9001. “Customer focus” is replaced by 5.1.2 “Focus on learners and other beneficiaries” which is the first management principle of EOMS. Furthermore, ISO 21001 has one more clause - 5.1.3 “Additional requirements for special needs education”.

Clause 6 “Planning” has the same structure for the two standards considered in this comparison. It comprises of: 6.1 “Actions to address risks and opportunities”, 6.2 “QMS/EOMS objectives and planning to achieve them”, and 6.3 “Planning of changes”.

Clause 7 “Support” has identical overall structure: Clause 7.1 “Resources”, Clause 7.2 “Competence”, Clause 7.3 “Awareness”, Clause 7.4 “Communication”, and Clause 7.5 “Documented information”. The main additions in EOMS in comparison to QMS are:

- Clause 7.1.6 “Organizational knowledge”: expanded with a new element 7.1.6.2 “Learning resources”;
- Clause 7.2.2 “Additional requirements for special needs education”;
- Clauses 7.4.2 “Communication purposes” and 7.4.3 “Communication arrangements”.

Just like most ISO management system standards, the core processes in ISO 9001 and ISO 21001 are concentrated in Clause 8. Here too, ISO 21001 is richer in content and expands basic QMS requirements.

For example, Clause 8.1 “Operational planning and control” is enriched with:

- Clause 8.1.2 “Specific operational planning and control of educational products and services”, and

- Clause 8.1.3 “Additional requirements for special needs education”.

Clause 8.2 “Requirements for products and services” has different number of sub-clauses and content in the two standards discussed (see Table 1).

TABLE 1 COMPARISON OF REQUIREMENTS FOR PRODUCTS AND SERVICES

ISO 9001:2015	ISO 21001:2018
8.2.1 Customer communication	8.2.2 Communicating the requirements for the educational products and services
8.2.2 Determining the requirements for products and services	8.2.1 Determining the requirements for the educational products and services
8.2.3 Review of the requirements for products and services	
8.2.4 Changes to requirements for products and services	8.2.3 Changes to requirements for the educational products and services

Clause 8.3 “Design and development of products and services” in ISO 21001 has the following additional elements:

- Clause 8.3.4.2 “Educational service design and development controls”;
- Clause 8.3.4.3 “Curriculum design and development controls”, and
- Clause 8.3.4.4 “Summative assessment design and development controls”.

All requirements for Clause 8.4 “Control of externally provided processes, products and services” in ISO 9001 and ISO 21001 are the same.

Clause 8.5 “Delivery of the educational products and services” in ISO 21001 is much more industry specific than ISO 9001. The content of Clause 8.5.1 “Control of production and service provision” is augmented in ISO 21001 with the following clauses:

- 8.5.1.2 “Admission of learners” that includes pre-admission information and conditions for admission;
- 8.5.1.3 “Delivery of educational products and services”;
- 8.5.1.4 “Summative assessment”;
- 8.5.1.5 “Recognition of assessed learning”, and
- 8.5.1.6 “Additional requirements for special needs education”.

Clause 8.5.2 “Identification and traceability” has the same title in both standards.

Nevertheless, its content is substantially different due to the different nature of educational services when compared to industrial products and other types of services.

Clause 8.5.3 “Property belonging to customers or external providers” in ISO 9001 is very similar to Clause

8.5.3 “Property belonging to interested parties”. The main differences are in the “Note” to this clause in ISO 21001 that lists “certificates, diplomas and other relevant documents” as examples of property of interested parties.

The requirements of Clause 8.5.4 “Preservation”, and only the “Note” from ISO 9001 is missing in ISO 21001.

Practically, Clause 8.5.5 “Post-delivery activities” of ISO 9001 is entirely different from Clause 8.5.5 “Protection and transparency of learners’ data” in ISO 21001 that deals with legal requirements and technological measures for data protection.

There are no differences in the content of Clause 8.5.6 “Control of changes in the educational products and services” in both standards.

Clause 8.6 “Release of products and services” is clarified with a “Note” in Clause 8.6 “Release of the educational products and services” in ISO 21001.

There is a minor change in the numbering of Clause 8.7 “Control of nonconforming outputs” in the two standards. ISO 21001 has an additional requirement to retain documented information that “describes the delivery of the programmes”.

Clause 9 “Performance evaluation” contains the same 3 sub-clauses in both ISO 9001 and ISO 21001. But their structure and focus are different. Clause 9.1.1 “General” is very similar in both standards, and Clause “Analysis and evaluation” in ISO 9001 is numbered as “9.1.3”, whereas in ISO 21001 it is “9.1.5”. Clause 9.1.2 “Customer satisfaction” is replaced in ISO 21001 by the following elements:

- Clause 9.1.2 “Satisfaction of learners, other beneficiaries and staff” which includes monitoring of satisfaction and handling of complaints and appeals;
- Clause 9.1.3 “Other monitoring and measuring needs”, and
- Clause 9.1.4 “Methods for monitoring, measurement, analysis and evaluation”.

Clause 9.2 “Internal audit” is substantially the same for both standards. Still, ISO 21001 requires that “Auditors shall not audit their own work.”. Both standards direct their readers and implementers to use ISO 19001 for guidance on auditing.

The differences in Clause 9.3 “Management review” are mainly in the inputs. In addition to the inputs required in ISO 9001, ISO 21001 also requires “formative and summative assessment outcomes” and “staff feedback related to activities to enhance their competence” are taken into consideration.

Clause 10 “Improvement” is structurally different in the two standards, the sequence of text is changed but the approach to improvement is identical (see Table 2).

TABLE 2 COMPARISON OF CLAUSE 10 “IMPROVEMENT”

ISO 9001:2015	ISO 21001:2018
10.1 General	10.3 Opportunities for improvement
10.2 Nonconformity and corrective action	10.1 Nonconformity and corrective action
10.3 Continual improvement	10.2 Continual improvement

B. Effect of Annex SL on the Future Revisions of ISO 9001 and ISO 21001

In 2024, Annex SL which serves as the backbone for creating the structure of both ISO 9001:2015 and ISO 21001:2018 has been changed. It now incorporates 20 terms and definitions that shall constitute an integral part of any ISO management system standard.

Climate change is the other factor that organizations shall deal with in their management systems.

There is a new requirement in Clause 4.1 “Understanding the organization and its context”: “The organization shall determine whether climate change is a relevant issue.”.

A “Note” was added to Clause 4.2 “Understanding the needs and expectations of interested parties”: “Relevant interested parties can have requirements related to climate change.”. In case they do have such requirements, organizations will have to prove that this issue is addressed in their QMS or EOMS.

To solve this emerging problem organizations may find helpful the following information by ISO:

- Guide 82 “Guidelines for addressing sustainability in standards” [11];
- Guide 84 “Guidelines for addressing climate change in standards” [12], and
- IWA 42 “Net Zero Guiding Principles” [13].

Another flagship ISO document that is related to the Annex SL structure and will have a significant impact on ISO standards, their linkage to the UN Sustainable Development Goals (SDGs), and their implementation in organizations is ISO/UNDP PAS 53002:2024 [14].

C. The Quality Management Systems of Two Bulgarian Universities

From a chronological perspective, ISO 9001 became popular in the early 1990s with the development of market economy and private businesses. Similar to the universities in other countries, Bulgarian universities aspire for ISO 9001 certification of their QMS in order to attract partners, researchers and students.

The QMS of the universities in Bulgaria is based on their internal management system that has to conform to the requirements of the National Evaluation and Accreditation Agency (NEAA). Thus, for some universities, the certification to ISO 9001 is considered an added cost with little or no value.

Only the universities with visionary leaders and staff who are competent in quality management and standardization see the untamed potential of developing, maintaining and improving a QMS/EOMS.

The first university considered in this paper was among the forerunners in teaching quality management. Initially it started as individual courses such as Quality Control, Quality Management Systems, Auditing Quality Management Systems, etc. Then it went on to create complete Bachelor's and Master's degree courses in the field of quality management. The professors were involved in internal and external auditor training and supported the development of the university's QMS. Even though efforts were made to develop and implement an ISO 21001-based EOMS, the lack of top management engagement and support suffocated the initiative.

The other university started in a similar manner. The main difference is that it focused more on the performance of the management system. This made the QMS leaner, agile and adaptable to the current context and emerging needs.

D. Auditing Educational Quality Management Systems

Both universities undergo internal audits performed by trained internal auditors, and external audits for accreditation done periodically by the NEAA. All three types of accreditation procedures (institutional accreditation [15], programme accreditation for professional field [16], and programme accreditation for a doctorate programme [17]) have specific criteria that are listed in 10 standards. Several of them deal with the "internal system of quality assurance". These NEAA audits are done by a team of experts from identical or similar scientific fields and coming from competitor higher education institutions.

The internal audits planned in the audit programme and initiated by an order of the rector of the university. Due to the nature of the academic calendar, usually internal audits are done twice a year, or once per semester.

Most often, the audits are done on-site by visiting the locations specified in the audit plan. The lead auditor establishes the concrete offices and timing based on the availability of the auditees who normally are professors and administrative staff. The preliminary audit plan is communicated to the team of internal auditors which is composed by the lead auditor (usually the Vice Dean for Quality of Education and Accreditation) and other audit team members who may be professors, administrative staff, students, involved representatives of business organizations, etc.

Another item to be considered in the preparation for the audit is risk. For example, the risk may occur from not closing nonconformities from previous audits, not auditing a specific department or degree programme for too long, turnover of teaching staff, introduction of new programmes, changes in curricula, changes in relevant legislation, upcoming accreditation procedures, etc. All these factors trigger an increase of the number and frequency of audits.

During the on-site audits the auditors complete their audit checklists and audit reports. Most of the questions are standardized and cover items such as: completeness and maintenance of educational documentation (curricula, test questions, ECTS information pages, exam grades and reports, graduation exams, etc.), planning and justification of classes taken, outsourcing of professors, assessments of teaching and administrative staff, awareness of the quality policy of the university, and other relevant elements.

The audit report is submitted to the Centre for Quality of Education (or a similar function within the university) and a copy is forwarded to the audited faculty and/or department. The audit findings are classified as: conformity, nonconformity (major or minor), opportunity for improvement or best practice/lesson learned. In case of a nonconformity, the auditee proposes corrective actions that are subject to approval by the auditor and/or the top management of the university.

The collected information and all audit files are stored at the Centre for Quality of Education. They are being summarized and presented at management reviews for the rector, the rector's team and the academic council. The information about internal audits is integrated in the yearly report of the university. Its public version is communicated to relevant interested parties, if necessary and upon request.

During the COVID-19 pandemic audits were done in a mixed mode. Everything that was available online was audited remotely using videoconferencing and sharing screens or files stored online. Physical distancing and limited working hours were respected in order to minimize health risks for the auditors and the auditees.

E. Recent developments in ISO 9001, ISO 21001, and ISO 19011

The standard with requirements for quality management systems is being updated as of 2025-01-17. The draft of the sixth edition of ISO 9001 is being reviewed by Technical Committee ISO/TC 176 "Quality management and quality assurance"/SC 2 "Quality systems" [18].

The second edition of ISO 21001 is at the Final Draft stage as of December 2024 [19]. Auditing requirements for EOMS are available since October 2023 when ISO/TS 21030 has been published [20].

The draft of the fourth edition of ISO 19011 is under development as of January 2025 [21].

IV. CONCLUSIONS

Education is intrinsically related to quality and one cannot go without the other.

This paper has demonstrated how the internal management system of a university can be established in accordance with the requirements of ISO 9001. For universities that wish to go beyond basic quality management, a solution to migrate the QMS to ISO 21001 is suggested. Both standards are auditable using ISO 19011.

In 2025 all of the abovementioned standards will be replaced by new editions and universities will have to update their existing management systems and practices.

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Improving Education for Future Marine Electromechanics Through Experimental Analysis of Hydrostatic Pressure in Liquids Using the HM 150.05 Experimental Unit

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Abstract—This study examines the integration of practical experimental methods into the Thermodynamics and Fluid Mechanics course for students specializing in Ship Electrical Equipment, focusing on understanding hydrostatic pressure in liquids. Using the HM 150.05 experimental unit, available in the Applied Mechanics Laboratory, the research aims to bridge theoretical knowledge with practical application. The experiment not only reinforces key principles linking thermodynamics and fluid mechanics but also provides students with a tangible understanding of the forces acting in the marine environment. The results highlight the effectiveness of experimental analysis in enhancing student comprehension and engagement.

Keywords — education, experimental learning, HM 150.05 experimental unit, hydrostatic pressure, Thermodynamics and Fluid mechanics.

I. INTRODUCTION

Education in the specialization of marine electrical equipment requires a solid foundation in courses in thermodynamics and fluid mechanics, especially to understand the behaviour of fluids when changing key thermodynamic parameters such as pressure.

HM 150.05 unit [1] serves as the main tool for providing students with practical experience in analysing hydrostatic pressure. This study offers a method for integrating this experimental unit into the educational process to enhance its efficiency.

Trainees specializing in Ship Electrical Equipment should be familiar with the basic principles of fluid mechanics. Sources [2] and [3] can be used in the educational process. These books provide an accessible

explanation of the causes of hydrostatic forces acting on various walls and curved surfaces, as well as how hydrostatic pressure is distributed in liquids. They also emphasize the significant influence of the fluid's depth on pressure and how this, in turn, affects submerged walls.

Once the trainees are familiar with and understand the core aspects of hydro-mechanics and have conducted the experiment, they can gain a practical understanding of the processes related to hydrostatic pressure in various ship structures and constructions. In [4] and [5], a detailed overview of the shipbuilding process is provided, including design, materials, structures, and systems. These sources examine the different stages of ship construction, from initial designs to the final built structure. In this context, understanding hydrostatic pressure and how it affects ship hulls, as well as ways to ensure the safety and stability of ship structures, the overall stability of the entire ship, and the effects of various loads, is of paramount importance for the entire crew and especially for mechanics and electricians.

The source [6] provides specialized information on hydraulic and pneumatic systems, covering key principles, components, and their application in engineering practice. The book can be used by both technicians and engineers, offering both theoretical explanations and practical examples related to thermodynamic principles of pressure, forces, energy conversion, and the importance of these systems in various industrial applications.

For future marine specialists studying Thermodynamics and Fluid Mechanics, it is crucial to understand how hydrostatic pressure influences the components of electromechanical systems. In [7], the

Online ISSN 2256-070X

<https://doi.org/10.17770/etr2025vol3.8530>

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dynamic characteristics and stability of electro-hydrostatic actuation systems, which use hydrostatic pressure for controlling mechanical movements, are explored.

Good theoretical preparation, conducting experiments using professional unit HM 150.05 type and connecting them with practical examples, will significantly increase and improve the knowledge and preparation of the trainees for their future practice at sea.

II. MATERIALS AND METHODS

HM 150.05 unit is designed to measure hydrostatic pressure in liquids at various depths. This demonstration allows students to establish the change in pressure with depth using the basic principle

$$p = \rho g t, \quad (1)$$

where: p, Pa – hydrostatic pressure.

$\rho, kg/m^3$ – density of water.

$g, m/s^2$ – gravitational acceleration ($g=9,81 m/s^2$);

t, mm – depth of the water column above the measurement point.



Fig. 1. HM 150.05 experimental unit.

Fig. 1 shows the HM 150.05 experimental unit, consisting of the following elements [1]:

1 – Water tank; 2 – Water level scale; 3 – Locking pin; 4 – Sliding weight; 5 – Stop pin; 6 – Slider; 7 – Weights.

The study is conducted through a series of experiments, including measuring the hydrostatic pressure at different angles of inclination of the water tank and recording the water levels. The experiments are carried out in the sequence described in the induction [1].

By calculating the hydrostatic pressure, the substitute force F_p is determined, which considers the pressure of the water on the curved wall. The experiment can be carried out at an angle of the water tank of $\alpha=0^\circ, 30^\circ, 60^\circ$ and 90° . In the present work, the results are shown only for the tank inclination of 0° and 60° .

The methodology of conducting the experiment is carried out in the following sequence:

- Determine the centre of pressure P, which is the point of application of the substitute force F_p , Fig. 2;

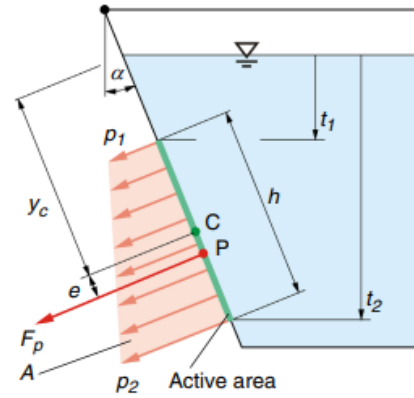


Fig. 2. Substitute force [1].

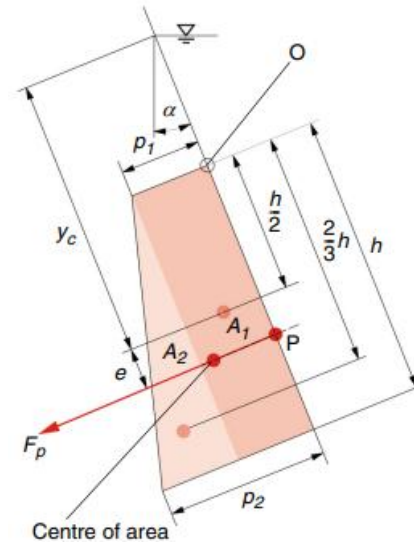


Fig. 3. Centre of pressure [1].

Fig. 3 shows the linear profile of pressure as depth t changes and how the distance e between the center of pressure P and the center of gravity C of the active area is determined.

- Determine the substitute force F_p at 0° and 60° position of the water tank, respectively [1].

The hydrostatic pressure acting on the active area A can be defined as a substitute force F_p whose directrix passes through the center of pressure P. The magnitude of this substitute force corresponds to the hydrostatic pressure at the center of gravity C of the active area:

$$p_c = \rho g t_c, \quad (2)$$

where: p_c, Pa – hydrostatic pressure in the center of area of the active area.

$\rho, kg/m^3$ – density of water.

$g, m/s^2$ – gravitational acceleration ($g=9,81 m/s^2$);

t_c, mm – vertical distance of the center of area from the liquid surface.

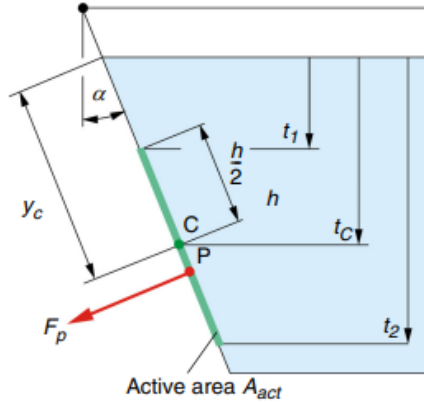


Fig. 1. Substitute force [1].

The substitute force can be found [4]:

$$F_c = p_c A_{act}, \quad (3)$$

The following assumptions are made for conducting the experiment:

- $\rho=1000 k/m^3$ – water density;
- $g=9.81 m/s^2$ – gravitational acceleration;
- $b=75 mm$ – width of water tank.
- Determining I_p – the distance from the centre of pressure P to the support point of the experimental unit.

After determining the hydrostatic pressure and the substitute force, the following is the determination of e – the distance between the centre of pressure P and the centre of the active area. It is involved in the formula for determining I_p . These two characteristics are calculated using different formulas depending on the slope of the water tank and the height of the water column.

$$I_p = 150 mm + e, \quad (4)$$

- Determination of the resultant moment M_p , the moment from the calculated values M_W and the error in percentage, i.e. the dispersion in percent [4]:

$$M_p = F_p I_p, \quad (5)$$

$$M_W = F_W I_W, \quad (6)$$

where: F_W, N – weight force;

I_W, mm – lever arm.

$$\frac{M_p - M_W}{M_p} 100\%. \quad (7)$$

A. Calculation of hydrostatic pressure for a non-inclined water tank – 0° position of the water tank

Fig. 5 shows how the distance I_p is calculated from the center of pressure P to the fulcrum of the experimental unit (lever arm). At a water level s above the $100 mm$ mark, the active area always has a height of $100 mm$. This means that the hydrostatic pressure on the active area has a trapezoidal profile. The hydrostatic pressure at the center of gravity is calculated using formula (8) [1].

$$p_c = \rho g(s - 50 mm), \quad (8)$$

where: s, mm – measured water level h .

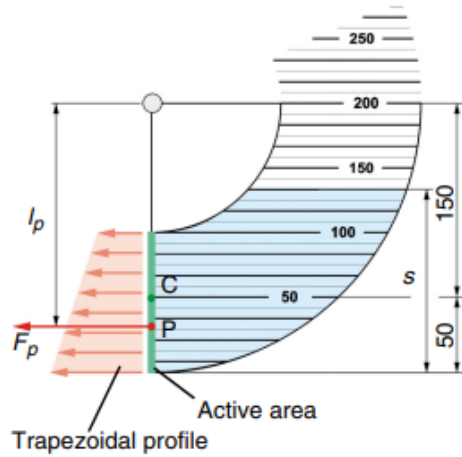


Fig. 4. Water level $s > 100 mm$ [1].

The area of the active area is calculated using the formula (9) [1]

$$A_{act} = b 100 mm. \quad (9)$$

The resulting substitute force is determined by the formula (10) [1].

$$F_p = p_c A_{act}. \quad (10)$$

The distance e between the centre of pressure P and the center of area C of the active area is determined by formula 11 [1], and the distance I_p by formula 12 [1].

$$e = \frac{1}{12} \frac{(100 mm)^2}{s - 50 mm}, \quad (11)$$

$$I_p = 150 mm + e. \quad (12)$$

The results of the water level measurements and calculations for the moment show that with increasing gravity force F_W and displacement force F_p , the water level

h increases, which is expected. At different angles of positioning of the water tank (0° and 60°) we observe different values of the measured characteristics.

The results obtained from the measurements and calculations of the main characteristics at a water tank position of 0° are shown in Table 1 and Table 2.

TABLE 1 RESULT OF MEASURED WATER LEVEL

Measurement №	Lever arm l_w, mm	Weight force F_w, N	Water level h, mm
1	140	0	-
2	140	1	50
3	140	1.5	60
4	140	2	69
5	140	2.5	78
6	140	3	84
7	140	4	98
8	140	5	110
9	140	6	122
10	140	7	136

TABLE 2 RESULT OF CALCULATED CHARACTERISTICS BASED ON MEASURED WATER LEVEL

Measurement №	Substitute force F_p, N	Lever arm l_p, mm	Moment M_p, Nmm	Moment M_w, Nmm	Variance %
1	-	-	-	-	-
2	0.92	183.3	168.6	140	20.4
3	1.32	180	238.3	210	13.47
4	1.75	177	310.3	280	10.8
5	2.24	174	389.4	350	11.25
6	2.59	172	445.5	420	6
7	3.53	167.3	590.7	560	5.4
8	4.41	163.9	722.8	700	3.25
9	5.3	161.6	856.5	840	1.96
10	6.33	159.7	1010.9	980	3.1

At the 0° position, the percentage error decreases with increasing force, starting at 20.4% and decreasing to 1.96% at the end.

Permissible error: 5% – 15% for experimental measurements in engineering disciplines.

At the 0° position, the errors are within the permissible limits, indicating that the experiment was successful.

B. Calculation of hydrostatic pressure for an inclined water tank – 60° position of the water tank

The difference between the analysis of an inclined and a vertical water tank lies in the conversion of the water levels to inclined active areas: The factor $\cos \alpha$ must be considered. Even when the water tank is inclined, a triangular profile is obtained for the pressure curve when the water level is below s_u and a trapezoidal profile, as shown in Fig. 6 and Fig. 7.

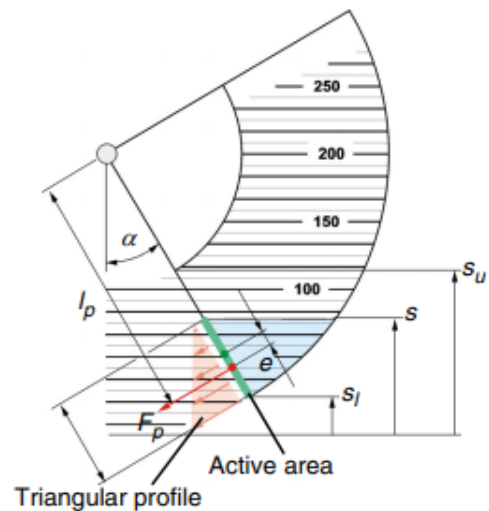


Fig. 5. Water level $s < s_u$ [1].

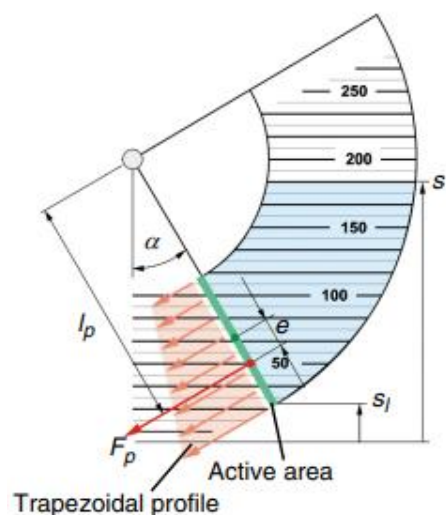


Fig. 6. Water level $s > s_u$ [1].

Before reading the water level h , it is necessary to read the water level at the lowest point of the water tank s_l and the water level at the upper edge of the active area s_u . This is done because when calculating the main characteristics

mentioned above, there is a comparison with the read water level s , which is h , with the parameter s_u .

At water level $s < s_u$ the pressure profile is triangular Fig. 6, then Formulas 13, 14 and 15 are used to calculate the parameters h , e and I_p [1].

$$h = \frac{s - s_l}{\cos \alpha}, \quad (13)$$

$$e = \frac{1}{6} h, \quad (14)$$

$$I_p = 200\text{mm} - \frac{1}{3} h. \quad (15)$$

At water level $s > s_u$ the profile is trapezoidal Fig. 7, then Formulas 16 and 17 are used to calculate the. parameters e and I_p [1].

$$e = \frac{1}{12} \cdot \frac{(100)^2}{\frac{s - s_l}{\cos \alpha} - 50\text{mm}}, \quad (16)$$

$$I_p = 150\text{mm} + e. \quad (17)$$

The next step is to determine the hydrostatic pressure at the centre of the area p_c , the area of the active area A_{act} , and the substitute force for hydrostatic pressure on the active area F_p . Here again, a comparison is made between the water level (which is the reported water level) and the water level at the top edge of the active area.

Again, different formulas are used to determine the above-mentioned characteristics depending on the pressure profile.

For a triangular profile (Fig. 8), Formulas 18 and 19 are used for $s < s_u$

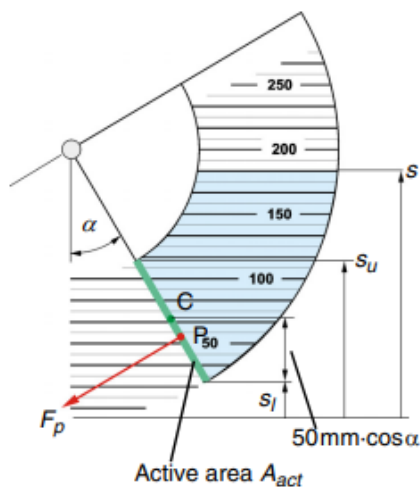


Fig. 7. Vertical water tank [1]

$$p_c = \rho g \frac{s - s_l}{2}, \quad (18)$$

$$A_{act} = \frac{s - s_l}{\cos \alpha} b. \quad (19)$$

and for a trapezoidal profile for $s > s_u$, Formulas 20 and 21.

$$p_c = \rho g (s - s_l - 50\text{mm} \cos \alpha), \quad (20)$$

$$A_{act} = 100\text{mm} \cdot b. \quad (21)$$

The resulting substitute force is calculated by the Formula 5.

To calculate the resultant moment from the calculated force, the resultant moment from the measured force and the dispersion in %, the formulas already cited above as in [1] used in the calculation of these characteristics at 0° position of the water tank are used.

The results obtained from the measurements and calculations of the main characteristics at a water tank position of 60° are shown in Table 3 and Table 4.

TABLE 3 RESULT OF MEASURED WATER LEVEL

Measurement №	Lever arm I_w, mm	Weight force F_w, N	Water level h, mm
1	140	1	130
2	140	1.5	140
3	140	2	147
4	140	3	158
5	140	4	170
6	140	5	182
7	140	6	194
8	140	7	206
9	140	8	220

TABLE 4 RESULT OF CALCULATED CHARACTERISTICS BASED ON MEASURED WATER LEVEL

Measurement №	Substitute force F_p, N	Lever arm I_p, mm	Moment M_p, Nmm	Moment M_w, Nmm	Variance %
1	0,497	182,67	90,79	140	35
2	0,954	176	167,9	210	20
3	1,360	171,33	233	280	17
4	2,134	164,37	350,8	420	16
5	3	160,20	480,6	560	14
6	3,9	157,86	615,6	700	12
7	4,78	156,41	747,6	840	11
8	5,81	155,41	902,9	980	8
9	6,7	154,58	1035,7	1120	75

At 60° , the variation of the moments (*% error*) remains relatively low until measurement 8 (8%), but at measurement 9 it suddenly increases to 75%, indicating a significant difference between the experimental and theoretical results.

In engineering experiments, the permissible error depends on the accuracy of the instruments and the application. The usual limits are:

Tolerable error: 5%-15% for experimental measurements in engineering disciplines.

If the error exceeds 20%, this may indicate:

- problems with the measuring instruments;
- human factor (error in reading);
- inaccuracies in the theoretical model.

At 60° , the error up to 8% is within normal limits, but the value of 75% in the last measurement indicates a serious deviation. Possible reasons:

- incorrect reading of the water level;
- a problem in the experimental setup;
- an error in the calculations.

III. RESULTS AND DISCUSSION

The experiments show that the HM 150.05 experimental unit provides accurate and reproducible data, allowing students to verify the basic hydrostatic laws. The data are analysed to demonstrate the dependence of pressure on depth and the inclination of the tank. Possible sources of errors are discussed, and how they can be minimized.

IV. OTHER RECOMENDATIONS

A. Review measurements for values with high error.

Check methodology and instruments.

B. Comparison with theoretical model.

If the difference remains large, the bench may need to be calibrated.

C. Repeat measurements.

For values with high error (e.g. 75%) it is good to repeat the experiment.

V. CONCLUSIONS

The use of the HM 150.05 unit in Thermodynamics and Fluid Mechanics course significantly enhances the educational process for students in shipbuilding and electrical engineering. Through direct participation in experiments, students gain a deeper understanding of basic principles and develop practical skills necessary for their future careers. This also stimulates their interest in scientific research and innovation in the field of marine engineering.

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Achieving Excellence in Computational Thinking: Insights from the ICILS 2023 Study

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Abstract— Computational thinking (CT) is often associated with computer science, but its versatility makes it a valuable tool for navigating life in a technology-driven world. CT serves as an essential educational skill, promoting problem-solving, critical thinking, and student engagement across various disciplines. Advanced CT skills help prepare students for the challenges of modern life and contribute to success in both professional and personal spheres. Previous studies show a strong connection between computational thinking and academic achievement, suggesting that developing these skills can enhance overall educational outcomes. The latest findings from the International Association for the Evaluation of Educational Achievement (IEA) International Computer and Information Literacy Study (ICILS) 2023, highlight significant differences in how students develop CT skills, raising important questions about equal access to quality education. This study uses data from ICILS 2023 to examine differences between schools where students excel in CT and those where these skills are less developed. Across nine participating countries, no significant differences were found in access to ICT resources or in teachers' use of ICT in and outside the classroom. Moreover, no specific curriculum topics stood out as key factors driving high CT performance in certain schools. However, students in top-performing schools were more likely to engage in independent learning on internet-related topics and demonstrated better focus during lessons. These schools also tended to accumulate students from higher socioeconomic backgrounds (SES) and were often located in larger cities or more affluent areas. In some countries, including Latvia, selective admission processes may further contribute to these students' strong performance—not just in CT but across a range of subjects.

Keywords— ICILS 2023, Computational Thinking (CT), International Large-scale Assessment, High CT Achievement Schools.

I. INTRODUCTION

Technology has profoundly transformed many aspects of modern life, making computational thinking an essential skill that extends beyond the field of computer science [1].

As digitalization continues to shape industries and everyday interactions, equipping students with computational thinking skills has become critical for success in the modern world.

Computational thinking provides individuals with the problem-solving tools needed to navigate complex challenges across various domains [2], [3], [4], [5]. Today, proficiency in computational thinking is not only a key factor in academic achievement but also a crucial competency for thriving in various professional fields [6].

As the demand for strong analytical, problem-solving, and algorithmic thinking skills continues to rise, educational institutions play a vital role in preparing students for the future. Schools must actively integrate computational thinking into their curricula, ensuring that students develop these critical skills at a level that enables them to confidently navigate both their personal and professional lives.

However, findings from the IEA ICILS 2023 study has exposed the uneven distribution of computational thinking skills among students, exposing significant disparities [7] sparking concerns that not all students are adequately prepared for success in a digital world.

This raises an important questions: Are all students equally prepared to tackle everyday tasks and challenges in a digital world?

This study aims to explore the differences between schools where students excel in computational thinking — referred to as top schools—and those with relatively lower performance. By examining the factors that contribute to the success of high-performing schools, this study seeks to identify key elements that impact student achievement. These findings could foster targeted interventions that improve academic performance in all educational environments, promoting equal access to quality education and enhancing student overall academic achievement.

Online ISSN 2256-070X

<https://doi.org/10.17770/etr2025vol3.8546>

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A. The Importance of Computational Thinking

In the realm of education, computational thinking is broadly understood as the ability to break down complex problems into smaller, manageable components and developing structured solutions [8], [9], [10], [11], [6], [12], [5].

The definition of computational thinking in the first cycle when it was introduced to the ICILS study as a separate domain in 2018 described it as a problem-solving approach in which problems are broken down into algorithmic, step-by-step solutions that can be executed by a computer. Following a review of recent literature and expert consultations, the definition of computational thinking remained consistent also in the 2023 ICILS cycle. It defines computational thinking as “an individual’s ability to recognize aspects of real-world problems that are suitable for computational formulation and to evaluate and develop algorithmic solutions to those problems, enabling the solutions to be operationalized with a computer” [13, p.38]

However, computational thinking goes well beyond just coding or programming. While often considered a skill tied to computer science, it is highly versatile and extends across various educational domains and subjects [14], [15], [10], [16]. Beyond simply imparting technical knowledge, the goal of computational thinking in education is to inspire creativity and innovation, encouraging students to become active problem-solvers. Many scholars trace the roots of computational thinking to Papert’s work in the late 20th century, which laid the foundation for much of the research in this field. Papert’s perspective on computational thinking is deeply intertwined with his constructionist educational philosophy, which emphasizes not only technical skills but also the social and emotional dimensions of learning. According to this approach, meaningful learning happens when students engage hands-on in creating systems and concepts [17]. By framing learning as a process of building and designing, constructionism fosters the development of problem-solving, debugging, and creative design skills—key elements of computational thinking.

More over, computational thinking plays a crucial role in enhancing students’ overall cognitive abilities, particularly their critical thinking skills [12]. These advanced thinking skills serve as a strong foundation for improving students’ academic performance and cognitive development. Supporting this, study conducted by Lei et al. [15] found a significant correlation between computational thinking and academic achievement. This highlights the importance of promoting computational thinking to strengthen both student learning and academic outcomes.

Furthermore, computational thinking promotes the development of essential abilities such as collaboration and communication [5], which support both intellectual and emotional growth. Previous studies show that collaborative problem-solving significantly enhances cognitive, social, and affective competencies [18], [19]. Collaboration not only deepens students’ understanding of CT concepts but also boosts emotional engagement and

motivation, making CT tasks more accessible and rewarding [19]. Collaborative problem-solving provides a practical context for students to develop and apply essential computational thinking competencies, preparing them for complex, cross-disciplinary problem-solving.

In summary, computational thinking is a valuable skill that extends beyond coding and programming, improving critical thinking, cognitive abilities, and academic performance. By fostering computational thinking, education can inspire creativity and innovation, promote problem-solving, debugging, and design skills, as well as to enhance collaborative problem-solving, communication and overall student academic performance.

II. MATERIALS AND METHODS

To investigate the variances among schools, this study utilized data from the IEA ICILS 2023.

The IEA ICILS 2023 is an international large scale assessment study, designed to evaluate students’ ability to use information and communication technology (ICT) effectively for various purposes beyond basic usage. It focuses on measuring student digital skills and competencies through realistic, computer-based assessments administered to eighth-grade students. ICILS has its roots in two earlier IEA studies: COMPED (*Computers in Education Study*) and SITES (*The Second Information Technology in Education Study*). These studies, conducted in the late 20th and early 21st centuries, laid the groundwork for a more comprehensive approach to assessing students’ digital competencies now known as ICILS [1].

Fraillon and Rožman [1] further explain that the ICILS study was officially launched in 2013, marking the beginning of a systematic international effort to evaluate students’ computer and information literacy (CIL) skills. The second cycle followed in 2018, introducing an optional computational thinking component – which is analysed in this study. CT module aimed to assess students’ ability to tackle real-world problems using ICT-based strategies. ICILS 2023 cycle included both CIL and CT module assessments, though participation in the computational thinking module remained optional.

ICILS 2023 used several instruments to collect data, with the primary source being the student assessment. This assessment is divided into two modules: the CIL assessment module and the CT assessment module.

CIL in ICILS 2023 is defined as “an individual’s ability to use computers to investigate, create, and communicate in order to participate effectively at home, at school, in the workplace, and in society” [20, p.26]. The CIL assessment is structured around four strands: Strand 1, *Understanding computer use*, which includes the aspects of Foundations of computer use and Computer use conventions; Strand 2, *Gathering information*, consisting of Accessing and evaluating information and Managing information; Strand 3, *Producing information*, covering transforming information and creating information; and Strand 4, *Digital communication*, comprising sharing information and using

information safely and securely. In parallel, Computational Thinking is organized into two main strands: Strand 1 *Conceptualizing problems* and Strand 2 *Operationalizing solutions*. These strands are further divided into key processes that define CT. Strand 1, focusing on conceptualizing problems, includes understanding digital systems, formulating and analyzing problems, and collecting and representing relevant data. Strand 2, dealing with operationalizing solutions, encompasses planning and evaluating solutions and developing algorithms, programs, and interfaces [7], [11].

The *Student Questionnaire* assesses students' backgrounds, access to ICT, experiences with technology, and attitudes toward its use at home and in school. The *Teacher Questionnaire* collects information about teachers' backgrounds, their use of ICT in the classroom, professional development experiences, confidence in using technology, and their emphasis on computer and computational thinking skills in their teaching. The *School Principal Questionnaire* provides insights into school characteristics, policies, ICT integration in teaching, and leadership in technology use. The *ICT Coordinator Questionnaire* is designed to gather data from ICT coordinators on available resources, technical support, and the overall integration of ICT in teaching and learning. Finally, the *National Contexts Survey*, completed by national research centers, captures information about the structure of the education system, the role of CIL in the national curriculum, ICT policies, and how computational thinking is incorporated into educational strategies [7], [11].

Data evaluation relies on two methods. The first is an automated process, where a computer program assesses responses based on predefined criteria. The second involves manual evaluation, in which trained assessors review and score responses according to specific guidelines. Additionally, the study uses a representative sample, ensuring that the findings accurately reflect the broader student population. This approach enhances the reliability and validity of the results, offering meaningful insights into students' competencies in computational thinking and computer and information literacy [21].

This study examines ICILS 2023 data from nine countries where students' average achievements in computational thinking are statistically higher than the overall study average: Belgium (Flemish), Chinese Taipei, the Czech Republic, Denmark, Finland, France, Latvia, the Republic of Korea, and the Slovak Republic. On average, each of these countries had approximately 150 participating schools, with numbers ranging from 136 in Belgium to 210 in the Czech Republic.

In each country, the top 10% of schools with the highest achievements (referred to as "top schools") were compared to the remaining schools ("other schools"). The achievement gap in the CT module between top schools and other schools was highest in Latvia, Slovakia, and the Czech Republic, with respective differences of 143, 122, and 116 points. Conversely, the smallest gaps were

observed in Denmark and Korea, with differences of 74 and 77 points, respectively.

Among these countries, Latvian students had the lowest overall average achievement. However, when focusing on top schools, Latvian students performed only slightly below those in the Czech Republic and Chinese Taipei and outperformed their peers in Korea and several other countries.

These significant disparities in achievement highlight a broader educational opportunity gap in these countries.

Apart from the CT achievement module, this study also utilized data from questionnaires completed by students, teachers, school ICT coordinators, and school principals across nine countries analyzed: Belgium (Flemish), Chinese Taipei, the Czech Republic, Denmark, Finland, France, Latvia, the Republic of Korea, and the Slovak Republic.

Both individual responses to survey questions and indices constructed from specific responses were used in this study to identify differences between top-performing schools and their students compared to other schools and their students.

Greater achievement dispersion in a country indicates a higher level of inequality in educational opportunities. Notably, the analysis revealed significant differences in student scores, particularly in the CT module.

A significant achievement gap in CT was observed in Latvia, where top-performing schools demonstrated substantially higher scores in the CT module compared to other schools. The average difference in CT module scores between these two groups reached 143 points, the largest gap among the nine countries analyzed.

III. RESULTS AND DISCUSSION

One of the key characteristics of schools are their location. Do certain locations, such as large cities or small villages, offer any advantages? There is a common perception that students from wealthier backgrounds—typically found in urban areas—benefit from greater access to high-quality resources, such as private tutoring and advanced educational opportunities, etc., which can enhance their academic success. In contrast, rural schools frequently face challenges that urban schools may not, including fewer extracurricular opportunities, difficulties in recruiting and retaining qualified teachers, lower teacher salaries, and, consequently, persistent teacher shortages [22], [23]. These disadvantages contribute to disparities in student performance and educational outcomes. Furthermore, rural students may lack access to the same social networks, learning resources, and support systems that are more readily available in urban settings, further exacerbating the academic achievement gap and negatively affecting the overall quality of education. Research across various disciplines consistently indicates that rural schools tend to have lower academic achievement and fewer educational opportunities

compared to their urban counterparts [24], [25], [26], [27], [28], [29], [30], [31], [32], [33], [21].

As part of the ICILS 2023 study, school principals were asked about the population size of the area where their school is located. The response options included the following population size ranges: 3,000, 15,000, 100,000, and 1,000,000 residents.

In Belgium and Denmark, the distribution of top-performing schools did not significantly differ from that of other schools. However, in other countries, top schools were less commonly found in smaller communities and were more often located in medium-sized or large cities. For instance, in Latvia, 45% of all schools were located in cities with up to 15,000 residents, yet only 15% of the top schools are in such areas. Similarly, in Korea, while 42% of all schools were in cities with a population of one million, 62% of the top schools were situated in these larger urban centres.

Overall, there is a clear tendency for top schools to be more prevalent in larger cities and less common in smaller inhabited areas. This pattern suggests that students attending top schools may represent a selective segment of the overall student population in their respective regions. As previously mentioned, smaller communities may lack the necessary resources or conditions to support the same level of academic excellence as larger urban areas.

In four of the nine examined countries, private schools were more prevalent among top-performing institutions than among other schools. For instance, in Belgium, 78% of top schools were private, compared to 55% of other schools. A similar trend was observed in Denmark, where 64% of top schools were private, while only 35% of other schools fell into this category. In France and Slovakia, private schools accounted for 63% and 21% of top schools, respectively, compared to just 15% and 10% among other schools.

In contrast, private schools in Latvia made up only about 6% of all schools, and none were ranked among the top-performing institutions. In the remaining countries, the distribution of public and private schools among top schools was relatively similar. These variations suggest that the role of private schools in academic achievement differs across countries, likely due to differences in educational policies, school missions, and student selection processes.

For example, in Latvia, private schools are not primarily focused on high-achieving students. Instead, many primarily serve students who face learning difficulties or social disadvantages. Conversely, in other countries, private schools can contribute to significant academic inequalities, particularly when they emphasize academic excellence. Green [34] argues that students in private schools often have greater opportunities for higher academic achievement compared to their counterparts in state schools, primarily due to the extensive resources that enable a broad range of educational and extracurricular opportunities. However, academic advantage is just one aspect of the issue. Socioeconomic segregation is another

critical factor in educational equity, and it should not come at the cost of academic excellence. Private schools, which are often expensive, tend to be accessible mainly to students from affluent families, thus exacerbating disparities in educational opportunities.

Beyond variations in school type and socioeconomic factors, the quality of education is also shaped by the availability of essential resources, including teaching aids, learning materials, classrooms, and laboratories. In an increasingly digital world, access to information and communication technology (ICT) resources—such as computers, the internet, and specialized software—plays a crucial role in enriching both teaching and learning.

To evaluate the availability and utilization of ICT resources in schools, a targeted survey was conducted among school ICT coordinators participating in the ICILS 2023 study. The most important questions were consolidated into five indices to represent key aspects of the data, providing a comprehensive evaluation of schools' technological capabilities, infrastructure, and readiness to support ICT-based learning.

The first index *Availability of ICT Resources at School* measured the accessibility of school infrastructure for both teachers and students. It encompassed various aspects, such as internet access through the school network, allocated space for file storage, internet-based applications for collaborative work, remote access to the school network from home, and the use of a learning management system, among other factors.

The second index, *Available Tools*, integrated ICT coordinators' responses to questions regarding the availability of ICT resources within schools. This included a range of tools such as practice programs or apps, where teachers have the flexibility to select and design the questions posed to students, as well as multi-user digital learning games that incorporate graphics and inquiry-based tasks. Additionally, other technological resources and platforms that support interactive and engaging learning experiences were considered, providing a comprehensive view of the technological infrastructure available for educational purposes.

In a similar manner the third index was developed to assess the *Utility Software Available In Schools*. This index included a variety of essential tools, such as word processors for creating and editing documents, presentation software for developing multimedia-rich presentations, video editing software to support the creation of visual content, and digital textbooks that provide interactive learning resources.

The fourth index summarized *The Hindrances Related To Computer Resources* while the last, fifth index integrated answers to the questions about *Pedagogical Resources That Affect The Use Of ICT In Teaching And Learning*.

A comparison of index values between top-performing schools and other schools did not reveal any consistent advantages for either group. The index *Available Tools*

showed no statistically significant differences between the two school groups in any of the countries analyzed. However, the index *Utility Software Available In Schools* recorded higher values in Chinese Taipei and the Czech Republic ($p < 0.05$), suggesting a greater presence of such resources in these countries.

The values of the *Hindrances Related to Computer Resources and Pedagogical Resources That Affect the Use of ICT in Teaching and Learning* indices showed statistically significant differences in only one country. Notably, these differences followed opposite trends: in Latvia, the lack of pedagogical resources was less pronounced in other schools, whereas in the Slovak Republic, computer resource shortages had a smaller impact on teaching and learning in other schools.

The results from the index *Hindrances Related to Computer Resources* varied across countries, with top schools in the Czech Republic and Finland receiving higher ratings, while in Korea, other schools reported better ICT resource availability. This suggests that top-performing schools are not necessarily better equipped with ICT resources compared to other schools. Consequently, the substantial differences in student achievement cannot be solely attributed to disparities in access to pedagogical or computer resources, indicating that other factors may contribute to these variations in performance.

Overall, these findings indicate that top schools are not necessarily better equipped with ICT resources than other schools. Likewise, the lack of pedagogical or computer resources does not appear to be a determining factor in the significant differences observed in student achievement. This aligns with ICILS 2018 results, which indicates that merely providing students and teachers with ICT equipment is insufficient for improving digital skills. Students need structured guidance on using digital tools effectively, while teachers require support in integrating ICT into their teaching practices to maximize its benefits [35].

In addition to ICT-related challenges, equity in education is also reflected in variations in student achievement, including gender-based differences. One key equity indicator examined in ICILS 2023 is gender equality in educational outcomes. Among the participating countries, girls outperformed boys in three countries — Chinese Taipei, Finland, and Korea. In two countries, Latvia and Denmark, no significant gender differences were observed. In the remaining four countries, boys had higher achievement levels, with statistically significant differences ($p < 0.05$) recorded in the Czech Republic and Belgium.

Despite these variations in overall performance, the proportion of girls and boys in top-performing schools was generally balanced, with two notable exceptions. In the Slovak Republic, boys comprised only 41% of students in top schools, whereas in Belgium, they accounted for 66%.

However, an interesting trend emerged when analyzing the performance of students in top schools. Although girls

achieved higher scores on average in some countries, boys in top schools consistently outperformed their female peers across all participating countries, with score differences ranging from 8 to 17 points. This gap was statistically significant in the Czech Republic, the Slovak Republic, and Belgium.

Given the increasing emphasis on promoting female participation in ICT-related fields, such as the EU's digital transformation goals for 2030—which aim to employ 20 million ICT specialists across the EU, ensuring equal gender representation in the field—these findings highlight the urgent need for greater focus on girls' engagement in ICT subjects from an early age [36]. Strengthening efforts to encourage girls' interest and confidence in technology-related disciplines, particularly at the primary and lower secondary school levels, is essential in addressing current gender imbalances and fostering more balanced representation in ICT careers in the future.

By analyzing students' responses to survey questions, it is possible to gain insight into the skills taught in schools as well as those developed independently outside of school. It can be assumed that higher achievements in the CT test are linked to a more comprehensive study of relevant CT topics in the school curriculum. These responses were gathered in the *Learning About CT in Class* index, which combines students' answers to questions about what was taught in school, including:

- Use a solution that works for one problem to help solve a different problem.
- Solve a hard problem by splitting it into a few easier problems.
- Make diagrams that explain concepts or systems.
- Plan tasks by making a list of the tasks in the order they need to be completed.
- Detect patterns in data.
- Use simulations to help understand concepts or systems.
- Make flow diagrams to show how a computer program should work.
- Systematically test computer programs to find bugs, errors, or other problems.
- Use data to better understand real-world problems.

Only in Chinese Taipei and Latvia were the index values statistically higher for students in top schools. In three countries—Czech Republic, Denmark, and France—the index value was statistically higher for students in other schools. None of the examined questions yielded responses in which students from top schools across all analyzed countries consistently provided more positive answers. In four countries, top school students were more likely to have learned how to make diagrams that explain concepts or systems. However, the activities of making flow diagrams to show how a computer program should work and systematically testing computer programs to find bugs, errors, or other problems were performed significantly more

often by students in other schools in almost all countries (except for Chinese Taipei and Belgium).

On the other hand, in all countries, students in top schools more frequently used word processing software (with statistically significant differences in five countries) and computer-based information resources (with statistically significant differences in seven countries). In seven countries, students in top schools also more often used presentation software (with statistically significant differences in four countries).

We can conclude that teaching CT topics in schools is not critical for achieving high skills in this field. Equally important are tasks related to computer literacy. It should be noted that the ICT self-efficacy regarding the *Use Of General Applications* index values were higher for top school students in all countries, whereas the values for the *ICT Self-Efficacy Regarding The Use Of Specialist Applications* index were not statistically significantly higher for top school students in any country.

High achievements are more likely to be explained by students' activities outside of school. Students in top schools across all the examined countries more frequently engaged in internet-related tasks outside of school (with statistically significant differences in five countries). They also searched for information online more often in all countries except Denmark. In all countries, students in top schools outside of school were more likely to evaluate whether the information they received was truthful. In eight countries, students in top schools were more likely to manage privacy settings for their internet accounts and ICT devices at home.

Attention should also be given to the learning styles of students in top schools. During class time, these students were significantly less likely to engage in activities such as text chatting with others, using social media to post or view content, checking social media for new posts or responses to their posts, or watching online videos, live streams, or television. The corresponding index for *Academic Media Multitasking* showed lower values for top school students in all countries, with six countries showing statistically significant differences.

This pattern suggests that students in top-performing schools may have greater opportunities or motivation to develop self-directed learning skills. During class, these students are less likely to engage in activities such as texting, browsing social media, or watching videos. This behavior could indicate a stronger focus on academic tasks, which may contribute to their overall academic success. By minimizing multitasking and distractions, these students may engage more effectively with the material. They also seem to have a stronger sense of digital responsibility, which affects not only their academic engagement and achievement but also their safety and security in digital environments. These findings highlight the crucial role that out-of-school engagement with technology plays in academic success. The evidence emphasizes the importance of cultivating digital literacy, critical thinking, and responsible online behaviors outside of school hours. Additionally, top-performing students are often more

disciplined in managing their time and media consumption, which may contribute to their higher academic achievements.

Finally, but no less importantly, the socio-economic status (SES) of students in top schools should be highlighted. In all the countries examined, the average SES of students in top schools was significantly higher ($p < 0.01$). This indicates that, in most of these countries, top schools have developed as institutions that select students in some way. They may be private schools or located in areas (districts) with relatively wealthy populations. In Latvia, six of the top schools are gymnasiums, which require entrance exams and competitions for admission to the seventh grade. In contrast, neighbouring Estonia adopts a different approach: schools do not categorize students based on academic performance during admissions. Instead, they operate under the premise that all primary education students have mastered the curriculum at a minimum standard. Remarkably, despite this inclusive admission policy, Estonian students still achieve high results in the OECD PISA assessments [37].

However, not all top schools are associated with high socioeconomic status (SES), and this cannot be generalized to all top schools. For instance, one of the top schools in Latvia is situated in a small settlement where the average SES of its students is very low.

To sum up - the concentration of high-achieving students in selective schools creates an environment that nurtures excellence. However, it also raises concerns about unequal access to quality education.

In contrast, the existence of a top-performing school in a low socioeconomic status (SES) area—such as one observed in Latvia—suggests that success is not solely dependent on economic status. This situation prompts a crucial question: What is this school doing differently, and what can we learn from it? Is this correlation a coincidence, or is there a causal relationship at play?

These findings underscore the need for further research into high-performing schools in low-SES areas. Understanding the factors behind their success could inform strategies to promote greater equity in computational thinking education. Additionally, identifying the key practices that enable some lower-SES schools to thrive may offer valuable insights for creating a more inclusive and effective learning environment. By learning from these examples, policymakers and educators can develop targeted interventions that support underprivileged students and help close the achievement gap.

IV. CONCLUSIONS

The findings of this study indicate that high achievement in computational thinking is not solely determined by access to ICT resources or the formal teaching of CT topics in schools. Across the nine examined countries, a comparison between top-performing schools and other schools revealed no significant differences in ICT availability, infrastructure, or resource accessibility. Additionally, the curriculum did not appear to play a

decisive role, as there were no specific CT-related topics that consistently correlated with better student performance across all countries. This suggests that the development of computational thinking skills is influenced by a broader set of factors beyond just classroom instruction or access to technology.

Instead, the study highlights the importance of general digital literacy skills, including proficiency in word processing, presentation software, and information retrieval, as crucial components that contribute to computational thinking.

The study also highlights the importance of out-of-school engagement with technology. Students in top-performing schools were found to engage more frequently in independent, self-directed learning related to ICT outside of school. They were more likely to use online tools for educational purposes, critically evaluate digital information, and take an active role in managing their own learning. This indicates that self-directed learning and a strong sense of digital responsibility are important contributors to academic success. Moreover, these students showed better time management skills, suggesting that effective media consumption and minimizing distractions during class time can enhance academic focus and performance.

Another important finding is the strong connection between socioeconomic status (SES) and high CT achievement. In all participating countries, students attending top-performing schools tended to come from higher SES backgrounds, with these schools often being concentrated in urban or more affluent areas. In some countries, selective admission policies further contributed to this trend, leading to an environment where academically strong students were concentrated in specific institutions. This raises concerns about educational equity, as students in rural areas or from lower-income families may not have access to the same level of resources or academic opportunities that foster computational thinking development.

Additionally, gender disparities in computational thinking performance were observed. While girls outperformed boys in overall CT scores in some countries, boys in top-performing schools scored higher than their female peers. This pattern suggests that while girls demonstrate strong computational thinking abilities, they may not be equally encouraged or engaged in CT-related activities at the highest levels. Given the increasing importance of CT in future careers, targeted efforts are needed to ensure that girls receive the same level of support, confidence-building, and exposure to computational thinking opportunities as boys.

Beyond in-school learning, students' habits and behaviors during class were also linked to high achievement in CT. Students in top-performing schools were less likely to engage in distractions such as social media, messaging, and entertainment during lessons. This suggests that focused classroom engagement, better time

management, and reduced digital distractions contribute to stronger academic outcomes in CT.

To sum up, this study reveals that high achievement in computational thinking is influenced by a variety of factors beyond just access to ICT resources or formal classroom instruction. While resources and curriculum did not show a clear correlation with higher student performance across countries, key factors such as general digital literacy, self-directed learning, and strong time management skills emerged as important contributors to success. Students in top-performing schools were more likely to engage in independent learning, critically evaluate digital information, and manage their own educational processes, indicating that self-motivation and digital responsibility are vital for academic achievement. Additionally, socioeconomic status played a significant role, with top-performing schools often located in more affluent areas, raising concerns about educational equity. Gender disparities in CT performance also highlighted the need for increased support for girls in the field. Ultimately, the findings suggest that while ICT resources are important, the development of computational thinking is shaped more by students' learning habits, socioeconomic backgrounds, and overall digital literacy than by the availability of technology alone.

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Feature of Engineering Training for Future Technology Teachers

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Abstract- A study of the ideas of future technology teachers about technical phenomena in machines showed that their interpretations are unsuitable for organizing the educational process of studying the basics of technology by students. Accordingly, they will not be able to orient lyceum graduates to engineering education. The purpose of this study was to form the interest of future technology teachers in the adapted content of engineering training, suitable for organizing specialized training of lyceum students in studying the basics of technology. The levels of cognitive interests of students were assessed according to qualitative criteria: cognitive activity, nature of interest, independence, nature of use of free time, method of overcoming cognitive difficulties. Quantitative data were collected using questionnaire and testing methods. The null hypothesis of the absence of significant differences in the level of change in students' cognitive interest in technical phenomena was not confirmed in the experimental group, but was confirmed in the control group. The results of this study are important for developing university work programs. The practical value of the research results for the training of students of non-technical specialties lies in defining the concept of a technology user for ideological knowledge about machines. The potential international value of the research results lies in defining technical phenomena in machine drive as a basic concept for the formation of a technical worldview.

Keywords-engineering training, ideological knowledge about the technological machine, interest in technical phenomena, technology teacher.

I. INTRODUCTION

The content of engineering training of future teachers of technology in Ukraine is irrelevant to the tasks of their professional activity, so students are not interested in the formation of engineering competence. This fact is a reflection of the inertia of the system of technological

education of schoolchildren. To form the content of engineering training of future teachers of technology, the concept of a holistic view of the production process from the last century is used. Accordingly, in the profile education of students, there is no study of the basics of technology and they do not form the ability to self-determination regarding training in the engineering specialty.

The concept of a holistic view of the production process determined the choice of the curriculum for the training of a design engineer in the mechanical engineering industry as the basis for the formation of engineering training of a future teacher of technology. In fact, the requirement that technical knowledge be used by future teachers of technology to solve pedagogical tasks in the technological education of students is neglected. Accordingly, in Ukraine, the content of technical science is differentiated according to two types of technical training of students - general technical and machine-learning. General technical training of students is the basis for the formation of machine learning training. So, in practice, engineering training of future technology teachers is considered a synthesis of general technical and machine learning training. We studied the aspect of improving machine learning training of future technology teachers. Since there is an interrelation between these types of technical training, general technical training will also be subject to reconstruction, but in further studies of this problem.

The object of the study was the process of engineering training of future teachers of technology. The subject of the study was the cognitive interest of students in technical phenomena in the machine drive. The purpose of the study was to use the method of solving technical problems to form the cognitive interest of students. The basic component of the didactic conditions for the formation of students' cognitive interest was the innovative content of

Online ISSN 2256-070X

<https://doi.org/10.17770/etr2025vol3.8519>

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technical knowledge about technological machines, which corresponds to the cultural and axiological methodological approaches [1; 2; 3]. The main idea of these approaches was to study technological machines as artifacts of material culture and to form a technical worldview in students as a means of orientation in social values. Thus, engineering training of future teachers of technology should be used in their professional activities to organize the study of the basics of technology by students in order to make a decision to study engineering specialties [4; 5]. The results of scientific research by C. Mitcham on the feasibility of using information projects about technical phenomena in technical objects in student education were also taken into account [6].

In previous studies, we justified the choice of the drive of a technological machine as a source of generalized knowledge about the physical foundations of the functioning of any machines [7]. A general idea of a technological machine was expediently obtained by studying the essence of such basic technical phenomena: motion transmission in space, change in kinematic parameters of motion, change in force parameters of motion. Our further studies were aimed at analyzing the curriculum for training a mechanical engineer as a support for selecting the content of technical knowledge about a technological machine for future technology teachers [8]. A future technology teacher is a user of technological machines, not a developer, therefore the activities of a mechanical engineer were considered by us as a standard of a technology user. The effectiveness of studying the basics of technology by students of non-technical specialties according to the user concept was reported in the study by J. Kropats [9]. M. Barak et. al argued that generalized knowledge about a machine is a description of the nature of the transmission of engine power to its working body [10]. According to E. Crawley et. al knowledge about the energy patterns of the functioning of a technological machine is relevant to the content of the process of its operation [11]. S. Purzer et. al came to the conclusion that engineering knowledge about the patterns of the functioning of the drive of a technological machine is available for assimilation by schoolchildren [12]. M. Marusic et. al recommended forming students' cognitive interest in technology on the basis of worldview knowledge, the core of which will be generalized knowledge about the machine as a trigger of conscious self-determination regarding training in engineering specialties [13]. The hypothesis of the study was the assumption that cognitive interest in technology in future technology teachers will be formed under the condition of organizing practical classes in the academic discipline "Working Machines" as a process of solving a system of educational tasks about technical phenomena in the drive of a machine. Accordingly, the following research tasks were set: to develop a system of educational tasks about technical phenomena in the drive of a technological machine; to develop a program and methodology of a pedagogical experiment; to conduct a pedagogical experiment to confirm or refute the working hypothesis of the study.

II. MATERIALS AND METODS

V. Lamanaskas considered the technological education of schoolchildren as a means of their spiritual and social development, and not only as a means of forming design and technological competence in them [22]. We consider the knowledge of the essence of modern professions as a means of social development of schoolchildren. The social development of schoolchildren will contribute to their self-determination about further education in engineering specialties. To do this, it is necessary to reconstruct the traditional content of engineering training of future technology teachers. Future technology teachers must be able to interest schoolchildren in the profession of an engineer. The trigger for professional self-determination of schoolchildren should be cognitive interest in generalized knowledge about a modern machine. Generalized knowledge about a machine characterizes any type of machine. They are the result of integrating knowledge of mechanics with the content of engineering training of future technology teachers.

We began the search for generalized knowledge about the machine by changing the traditional concept of forming a holistic idea of the production process to the concept of a user of equipment [7; 15]. The traditional concept of a holistic view of the production process for future technology teachers considers the technological operation as its smallest component. They try to achieve integrity by forming in students the ability to describe a specific technological process as a set of interconnected technological operations. The innovative concept of the user of technical devices (equipment) considers mechanical motion as the smallest content element about technical devices. A holistic view of any type of modern machine is proposed to be achieved by forming in students the ability to describe the transformation of mechanical motion parameters on the way from the engine to the working body.

We considered the mechanical engineer as a reference user of equipment, capable of competently operating, servicing and repairing it. The content of engineering education of future teachers of technology was reoriented from a holistic idea of the production process to a holistic idea of the machine as an implemented technology of using engine energy to perform useful work. To confirm or refute the assumption that the new content of the educational material for the organization of engineering training of future teachers will contribute to the formation of cognitive interest in machines in them, a program and methodology of a pedagogical experiment were developed.

The pedagogical experiment was attended by 25 third-year students of the Mykhailo Kotsiubynskyi Vinnytsia State Pedagogical University, who are studying in the speciality 014.10 "Secondary Education (Labor Training and Technologies)". Among them, 15 (60%) were female, 10 (40%) were male, the age of women and men was 19 years. Over the course of two years, two series of the pedagogical experiment were conducted, each lasting 16 weeks, and the total array of experimental data was processed using mathematical statistics methods at the beginning of 2025. The total volume of the database, two series of the pedagogical experiment, covered 95% of the

total population of third-year students of the speciality 014.10 "Secondary education (Labor training and Technologies)" of the Mykhailo Kotsiubynskyi Vinnytsia State Pedagogical University. To assess the reliability of the shift in the levels of students' cognitive interests, taking into account the small sample size, the non-parametric G-criterion of signs (McNemar's test) was used [14]. It is used to compare the results of two small samples. In doing so, the following actions are performed: calculate the arithmetic means of the two samples; formulate statistical hypotheses; record the indicators for each respondent at the beginning and end of the experiment; compare the indicators and assign the appropriate signs (+, 0, -); calculate the empirical value of the sign criterion; find the critical value of the sign criterion from the table; test the statistical hypotheses.

At the ascertaining stage of the pedagogical experiment, an array of experimental data was collected using the questionnaire method (criterion of students' understanding of the purpose of transforming the parameters of mechanical motion in a machine). At the formative and control stages of the pedagogical experiment, an array of experimental data was collected using the methods of observation, conversation, testing and questionnaire. The following characteristics were assigned to the actual levels of development of students' cognitive interests: low level (-), medium level (0), high level (+). The level of formation of students' cognitive interests was assessed by the following qualitative characteristics: cognitive activity (criterion of the nature of questions and going beyond the curriculum), the nature of cognitive interests (criterion of interest stability), independence (criterion of seeking advice), the nature of the use of free time (criterion of the amount of free time spent), the way of overcoming cognitive difficulties (criterion of the nature of prompts). The transition from qualitative indicators to quantitative ones was carried out according to the following interval scale of cognitive interest levels: +3 ... +5 - high level; +2 ... 0 - medium level with a predominance of active cognitive interest; 0 ... -2 - medium level with a predominance of passive cognitive interest; -3 ... -5 - low level of cognitive interest.

To test the working hypothesis of the study, the method of solving educational technical problems was used in practical classes on the academic discipline "Working Machines". A system of types of educational technical problems was used. The following types of educational technical problems were used: to understand the essence of technical phenomena in the machine drive; to analyze technical phenomena in the machine drive; quantitative problems about the gear ratio; problems for constructing kinematic diagrams of gearboxes with missing elements in their condition; problems for constructing kinematic diagrams of gearboxes according to the spatial arrangement of the driving and driven shafts. The system of educational technical tasks directed the educational and cognitive activity of future technology teachers in a deductive direction from the essence of technical phenomena in the drive of machines to technical solutions of elements of power chains (reducers, gearboxes, feed boxes) and from

technical solutions of individual elements of power chains to technical solutions of power chains (main motion drives and drives of feed motion of metalworking machines, transmissions of cars). The sequence of using the types of educational tasks we chose allowed us to form and develop in students the components of technical thinking, in particular, technical knowledge integrated with elementary knowledge of mathematics and physics; operating with knowledge of technical phenomena in the drive of machines; operating with graphic images of elements of kinematic schemes; operating with knowledge of technical phenomena in the drives of machines in combination with images of elements of power chains of machine drives; operating with images of elements of power chains of machine drives, if the condition of the technical task does not have enough data for its solution.

III. RESULTS AND DISCUSSION

The results of assessing the actual levels of cognitive interests of third-year students of Vinnytsia State Pedagogical University named after Mykhailo Kotsiubynskyi in technical phenomena in the drive of machines at the beginning of studying the academic discipline "Working Machines" (stage of the ascertaining experiment) are given in Table 1.

TABLE 1 LEVELS OF COGNITIVE INTEREST OF STUDENTS

Years	The Number of Students According to the Level of Cognitive Interest, %			
	<i>Strong</i>	<i>Medium, with active interest prevailing</i>	<i>Medium, with passive interest prevailing</i>	<i>Low</i>
2023 - 2024	12	24	32	32
2024 - 2025	16	16	36	32

The analysis of the obtained results confirmed the fact of the presence of low and medium with a predominance of passive levels of cognitive interest of students in the study of technical phenomena in the drive of machines. We interpreted the obtained results as a lack of understanding by students of the potential opportunity to use technical knowledge in their future professional activities for the organization of student education. The homogeneity of the obtained results in two series of the ascertaining stage of the pedagogical experiment gave us grounds to divide the sample into experimental and control groups. In two series of the formative stage of the pedagogical experiment, practical classes in the academic discipline "Working Machines" in the experimental group of students were conducted using the method of solving educational technical problems developed on educational material of innovative content, and in the control group of students, a traditional methodology based on the educational material of the concept of a holistic view of the production process was used. To analyze the experimental array obtained at the formative stage, the method of calculating the G-criterion

of signs was used; the results obtained are given in Table 2 and Table 3.

TABLE 2 COGNITIVE INTEREST SHIFT

Groups	The Number of Students According to the Level of Cognitive Interest, persons											
	Strong			Medium, with active interest prevailing			Medium, with passive interest prevailing			Low		
	Shift			Shift			Shift			Shift		
	+	-	0	+	-	0	+	-	0	+	-	0
EXP			1	4		1	3	1		2		
CTR			1	1	2	2	2	2	1	1		1

TABLE 3 CALCULATION G-CRITERION

Groups	Total			G_{EXP}	Without the Zero Shift	G_{CRIT}
	+	-	0			
EXP	9	1	2	1	10	3
CTR	4	4	5	4	8	3

The inequality $G_{EXP} \leq G_{CRIT}$ served as a criterion for refuting the null hypothesis of the absence of changes in the levels of cognitive interests of students and, as evidenced by the results of the pedagogical experiment for the experimental group, it was refuted (Table 3). For the control group, the null hypothesis was confirmed (Table 3).

To theoretically substantiate the obtained quantitative results, we conducted an in-depth analysis of literary sources, and also studied the current state of engineering training of students of non-technical specialties, during which it was found out that for a long time in Ukraine the task of changing the content of engineering training of future teachers of technology was not set. Researchers did not pay attention to the fact that when training future engineers, the method of solving technical problems is used in the context of designing, constructing, manufacturing, and operating technical systems, and when training future technology teachers, this method is used in the context of forming technical literacy in schoolchildren as a trigger for conscious self-determination regarding further education in the engineering specialty.

Mechanical transfer to higher pedagogical education institutions of Ukraine of the content of engineering education based on the curriculum for training an engineer-designer in the mechanical engineering industry has not found practical use. The production process as a complex object of study for students cannot be used by future technology teachers to form the technical literacy of students. The first step to solving this problem was the division of engineering training of students into two categories - classical engineering training and engineering training in non-technical specialties (for example, future technology teachers) [16; 17]. That is, the focus is changed from the production process to the means of production. Then the means of production are narrowed down to the machine as its main component. However, the machine is

also a complex object for students to study, so the generalized functional scheme of the machine was studied, namely: engine - transmission - working body [7]. It was taken into account that the generalized functional scheme of the machine is an attribute of any technological machine, regardless of the technical solutions used to transfer energy from the engine to the working body.

The correct orientation for students in the world of technology is one of the main didactic conditions for the formation of cognitive interest in machines [18; 20]. The generalized functional scheme of the machine was chosen as a reference point. An analysis of studies on the generalized functional scheme was carried out. In particular, the conclusions of D. Broo et. al that in engineering education there is a convergence of various academic disciplines [1], the reason for this is that C. Hampton et. al characterized technical science as the border between natural sciences and humanities [17]. Van den Beem et. al argued that the nature of modern engineering education is clearly interdisciplinary [2]. The recommendations of researchers on the essence of the formation of technical knowledge in students were also taken into account. For example, the statement of S. Lottero-Perdue & Lachapelle et. al that technical knowledge is a means of solving the pedagogical task of diagnosing and forming students' abilities for engineering activities, as well as for the formation of students' technical thinking [15]. J. Pleasants et. al considered the concept of the user of technology as the basis for the formation of students' technical literacy [19], and J. Kropach used it for engineering training of students studying non-technical specialties [9]. S. Tzeng et. al recommended the content of educational material about technology for students with a low level of difficulty [18]. There are alternative recommendations that students' ideas about technology are formed in the process of obtaining technological education [8; 21], as well as V. Lamanauskas, that the basis of the organization of the educational process of studying technology is a competency-based approach [22].

Students' answers to the questions of the open questionnaire showed that for the first question there is a connection between understanding the content of the question and interest. The second question of the open questionnaire assessed students' interest in changing the power parameters of the chain transmission by a cyclist when moving uphill. The results showed a predominant influence on students' interest of life experience at the beginning of the pedagogical experiment. The third question of the open questionnaire assessed students' interest in the cyclist changing the kinematic parameters of the chain transmission when going downhill. Here, the predominant influence on students' interest was also recorded by life experience at the beginning of the pedagogical experiment. In the fourth question of the open questionnaire, students determined the correct placement of the principle of engagement and the principle of friction in the power chain of the mechanical transmission drive. At the beginning of the pedagogical experiment, this question was irrelevant, but at the end of the pedagogical experiment it changed its status. In the fifth question of the open questionnaire, students analyzed the kinematic diagram of

a worm gear and the kinematic diagram of a passenger elevator drive for the presence of the fractal property. The question turned out to be irrelevant and changed its status only at the end of the pedagogical experiment. In the sixth question of the open questionnaire, students had to explain why a cyclist increases the pedal rotation frequency when going uphill. The results of the answers showed the predominant influence on the interest of students of life experience at the beginning of the pedagogical experiment. In the seventh question of the open questionnaire, students were asked to determine the rate of fatigue of cyclists riding bicycles with wheels of large and small diameters. The results of the answers showed the partial irrelevance and influence on the interest of students of life experience at the beginning of the pedagogical experiment. In the eighth question of the open questionnaire, there were images of devices with which a bicycle is used for a new purpose, and students chose the correct combination of a bicycle and a device. At the beginning of the pedagogical experiment, the question was irrelevant, but at the end of the pedagogical experiment it changed its status. During the pedagogical experiment, tests were also used to continuously monitor the level of students' knowledge about technical phenomena in the drive of a technological machine as a means of assessing knowledge.

The results confirmed the feasibility of studying technical phenomena in machine drives by future technology teachers as generalized knowledge about machines. When organizing practical classes in the academic discipline "Working Machines" for future technology teachers based on the method of solving educational technical problems, the disadvantages included the presence of mosaic knowledge about technical phenomena in machine drives among some students. The feasibility of using the concept of a technology user to form engineering training for future technology teachers based on the curriculum for training a mechanical engineer as a reference user of technology was confirmed. The shift in the indicators of students' cognitive interest in the innovative content of engineering knowledge indicates the possibility of forming readiness for organizing the educational process of studying the basics of technology by students as a trigger for their conscious choice of future education in an engineering specialty.

The use of the concept of the user of technical devices in the process of solving educational tasks helped to interest a significantly larger number of students in the essence of modern machines. Therefore, we can talk about the effectiveness of the author's developments. At the same time, the main drawback, in our opinion, is the increase in the level of complexity of students' mental actions. Not all educational tasks in the pedagogical experiment performed the heuristic function of revealing the essence of the educational material. Accordingly, students made additional mental efforts to understand the conditions of educational tasks and find ways to solve them.

To interest schoolchildren in the profession of an engineer, in our opinion, teachers need to focus on the profession of a mechanical engineer. The basis of the performance of functional duties by a mechanical engineer

is generalized knowledge about any type of modern machine. To reduce the level of complexity of schoolchildren's mental actions, teachers need to integrate project methods and solving educational problems. Educational project activities of schoolchildren will perform the function of heuristics in the approach we propose.

IV. CONCLUSIONS

This study fills the existing gap in the literature on the use of cultural and axiological approaches to selecting the content of engineering knowledge in teaching students of non-technical specialties. Demonstrates their implementation to interest future technology teachers in knowledge about machines in the educational process organized using the method of solving educational technical problems. Students not only gain a deep understanding of technical phenomena in the machine drive, but also develop the ability to use educational technical problems to organize the process of studying the basics of technology by senior students.

The results of the study show that students whose engineering training was formed on the basis of the innovative content of the educational material demonstrated a higher level of cognitive interest in knowledge about machines, compared to those who were trained according to the traditional content of training according to the curriculum for the training of a design engineer in the mechanical engineering industry. The innovative content of knowledge about machines in the process of engineering training of students of non-technical specialties is a component of didactic conditions for the formation of cognitive interest in basic engineering in them. For future technology teachers, the process of forming an interest in the basics of technology should be integrated with their preparation for organizing specialized education of senior school students. The importance of such content of engineering training of future technology teachers is emphasized so that its results are relevant to their professional tasks. It is established that the new content of engineering training of future technology teachers is determined by the curriculum of training a mechanical engineer as a reference user of technology. To implement the concept of a user of technology, it is advisable to use a description of a generalized functional scheme of a machine with the basic concept of "technical phenomena of machine drive". In addition, this study encourages the formulation of a new task to determine the effectiveness of using innovative content of knowledge about machines for the development of technical thinking of future technology teachers. It is appropriate to recognize that a small sample size does not sufficiently represent the entire general population of future technology teachers in Ukraine. Future studies will need to use a blended learning or STEM education approach, a longer study period, and a larger sample size to fully assess the impact of the innovative content of educational material about machines on the development of cognitive interest in students of non-technical specialties. It is important that the content of engineering training of future technology teachers helps them solve professional tasks. The results of the study

provide grounds for their use in developing an improved work program for the academic discipline "Working Machines". The practical value of the concept of the user of technology for the formation of worldview knowledge about machines in students of non-technical specialties is established. The potential international value of the fact of choosing technical phenomena in the drive of a machine as a basic concept for the formation of students' technical worldview is revealed.

ACKNOWLEDGMENTS

The researchers express their sincere gratitude to the staff of the Mykhailo Kotsiubynskyi Vinnytsia State Pedagogical University for their assistance in conducting pedagogical research aimed at improving the engineering training of future technology teachers, as well as or valuable advice on the program of the pedagogical experiment.

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Assessing Cognitive and Creativity Competences in Pre-primary Children Based on Language Education Achievements

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Abstract—The research examines the assessment of preschool children's cognitive and creative competences based on their linguistic achievement. It highlights that in early childhood education, language skills are closely linked to the development of critical thinking, problem solving and creativity. Although international and national educational documents stress the importance of these skills, there is a lack of clear methodologies for assessing them in the educational process. The study used a quantitative analysis to develop a specific test (a set of tasks) to assess the cognitive and creative competences of children aged 5-6. The tasks of the test focused on the ability to understand and analyse texts, to create stories and to solve linguistic tasks. Data analysis was carried out using IBM SPSS software and Cronbach's Alpha coefficient was calculated to assess the reliability of the test. Descriptive statistics, paired t-tests and Spearman's correlation analysis were used. The results showed that there were no significant differences in cognitive and creative abilities between boys and girls, but there were individual variations in performance. Analytical competences proved to be slightly higher than creative competences, with no statistical significance. Note also that learning skills have a strong correlation with critical thinking skills and problem-solving bears a relationship to cognitive attainment. The research confirmed that language education composes an integral part of developing the child's cognitive and creative skills. These results can be further implemented in the training process by developing methodical materials of the pre-primary age based on the requirements for effective diagnostics of cognitive and creative abilities in children.

Keywords—preschool, smart ability, imagination ability, language teaching, child's evaluation.

I. INTRODUCTION

Relevance. The development of cognitive and creative abilities in children of preschool age is one of the priorities of modern education because the years spent in school are essential for the future success of the individual at personal and academic levels. International and national documents

on education stress that quality education in early childhood develops the critical thinking of the child, in addition to creativity and problem-solving ability [7], [4]. According to studies, stories and play are activities that help critical and creative thinking in children [18], [25].

The mastery of language shapes how children will develop their communication skills and contribute positively to the formation of aptitudes, both cognitive and creative [3]. Previous studies note that the integration of digital technology in early childhood education has a positive impact on creativity and problem-solving skills [2]. Also, STEAM-based learning, which stands for Science, Technology, Engineering, Arts, and Mathematics, has become a relatively strong tool regarding the fostering of creativity in the perspectives of early childhood education [24].

In its document, language education for the early years should be integrated with other competences, according to the National Education Agency [16]. It promotes self-expression, critical thinking, and experimentation with language in the child. The 2024 Inventory of Educational Achievements for Preschool Children highlighted to what extent output in language is related to children's abilities since through language they can analyse information, express themselves with ideas, and even solve problems [17]. So far, the educational documents have highlighted the need to check the cognitive and creative competences of children based on the effect of language learning. here is a scarcity of research on effective assessment strategies.

Novelty. Over the past two decades, scholarly literature has increasingly highlighted the importance of early childhood creativity and its connection with cognitive abilities [27], [9], [20]. Research has shown that children's creativity can be enhanced through storytelling, narrative, and digital storytelling, which foster both language development and analytical thinking [14], [18]. However,

Online ISSN 2256-070X

<https://doi.org/10.17770/etr2025vol3.8549>

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the practical assessment of these skills in pre-primary education is still without a common method.

Recent studies suggest that pedagogical strategies have a significant influence on children's creative and cognitive skills [28]. Many methods exist worldwide to apply certain criteria systematically to evaluate such competencies at educational institutions, yet there is little methodology for teachers in the use and control of competency assessment within the educational process. Another problem is that the methodology of measurement in the field of early childhood education is underdeveloped, leaving no opportunity to systematically assess children's cognitive and creative abilities to reveal their level of competence and development dynamics.

Issue. Cognitive and creative abilities constitute parts that are developed by pre-primary education but not directly traceable to successes in the acquisition of a language. Most of the assessment systems that are in use now concentrate on the general competences of children without having specific ways to relate these competences with the skills in language. The issue that is hence raised is how the cognitive and creativity competences of preschool children can be accurately assessed through their achievements in learning a language.

The aim of the study is to assess the cognitive and creativity competences of pre-primary children (aged 5-6 years) based on their language education achievements.

Study objectives:

1. To study educational documents and scientific literature on the development and assessment of cognitive and creativity competences and language learning achievements in pre-primary children (aged 5-6 years).

2. To develop, empirically validate and test a test (set of tasks) to assess the cognitive and creativity competences of pre-primary children (aged 5-6 years) based on their language education achievements

3. To analyse the results of a test (set of tasks) based on critical thinking and creativity indicators to assess the cognitive and creative competences of pre-primary children (5-6 years old) based on their language education achievements.

Methods:

- The study used a quantitative analytical approach to obtain objective data on children's cognitive and creativity competences. The research instrument was a specially designed test (a set of tasks) (hereafter referred to as 'the test'), the tasks of which focused on children's ability to understand and analyse texts, to create narratives and to solve linguistic problems.
- The data were analysed using IBM SPSS statistical software and Cronbach's Alpha coefficient was calculated to assess the reliability of the results, which showed the internal consistency of the test.

- The study employed descriptive statistics such as mean, median, standard deviation, skewness, kurtosis, and percentiles, statistical tests which include paired samples t-test and Shapiro-Wilk test, and Spearman's correlation analysis for the study.

The purpose of this study was to find out whether there is any significant difference between the cognitive and creative skill competence results of boys and girls and to determine the relationship between the said competencies. Based on the research objectives and method of data analysis described above, the following specific hypotheses are formulated:

H₀₁: The results for the boys and girls in cognitive and creativity competencies are not significantly different.

H₁₁: The results for boys and girls in cognitive and creativity competencies are statistically significantly different.

H₀₂: There is no significant relationship between cognitive and creativity competencies.

H₁₂: There correlation. is a statistically significant

II. MATERIALS AND METHODS

A. Literature review

A1. Methodological aspects and innovations in the language education of pre-primary children

Language acquisition comprises a vital part of early childhood education and develops not only linguistic competences but also social, cognitive, and emotional aspects. According to Vélez and Prieto [23], it is through literature and storytelling that children find a route for emotional expression and intellectual development. Personalized learning experiences resulting from various approaches in language education—narrative teaching, digital storytelling, and STEAM education, which integrates everything—mobilize students into abundant interaction [20], [18], [14].

Studies indicate that structured storytelling methods play a significant role in emergent literacy and social competence development in young children [1], [6]. Research further demonstrates that systematic language education in early childhood has a strong correlation with later academic success and personal development [7], [16], [17].

In the General Framework for pre-primary Education by the National Education Agency [16], language education is defined as involving listening and speaking, appreciation of the mother tongue, basic skills in reading and writing, and meaningful interaction with books and other print materials. It fosters among children active listening, verbal expression, exploration in writing, and the use of structured elicitation from texts to develop essential literacy competencies right from the start.

TABLE 1 LANGUAGE EDUCATION FOR PRE-PRIMARY CHILDREN

Area of achievement	Key indicators for language education
Listening, speech perception and speaking	Respect for mother tongue, dialect and other languages.
	Listens to others, expresses his/her own opinion and applies some rules of language etiquette.
	Listening to texts being read or narrated, discussing their content (events, time, place, characters), describes the theme of the text.
	Speak according to purpose and situation.
	Speaks coherently, stays on topic, speaks emotionally, uses non-verbal language.
	Playing with language, increasing vocabulary, understanding the figurative meaning of words.
Beginning reading and writing	Exploring and experimenting with language.
	Recognizes letters, reads short texts.
	Writes in block capitals and copies words.
	Explores books and identifies their structural parts.
	Talk about books, distinguish between verse and prose.
	Creates simple texts using visual expressions.
	Respect for mother tongue, dialect and other languages.

Compiled according to the pre-primary Framework [16].

Digital tools are also pivotal to the creativity nurtured by language education. As Robin [21] posits, digital storytelling gives children a chance to not only invent and imagine their stories but also reflect on content and structure. According to Su and Yang [22], interaction technologies bring diverse forms of expression, through which children can increase their imaginative powers. According to Blackwell et al. [2], early access to technology-enhanced learning environments greatly improves language skills and literacy at an early age.

Creativity can be firmly connected to the growth of one's problem-solving skills. According to Leggett [13], methods that encourage children to play with language help them acquire better communication skills and learn to find new solutions in various contexts. Another study by Jankūnaitė and Bagdonas [8] argues that game-based methods can develop the creative thinking of children much better since such methodology offers possibilities for playful uses of language and unexpected ideas to emerge.

In summary, the development of creative competence in the use of language is inseparably interwoven with the child's capacity for understanding and expression through language, as well as for fostering independent and original thought. Research consistently supports the amalgamation

of digital technologies, storytelling methodologies, and play-based learning as effective pedagogical approaches that enhance the creative and cognitive abilities of children [6], [25]. Additionally, storytelling methods, digital platforms, and game-based activities work as highly effective catalysts of linguistic creativity and self-expression. Thus, teachers should strategically apply these methods to help bring out the creativity in each child and to help every child find his or her individual, peculiar linguistic voice.

A2. The Harmony of Cognitive Skills in Language Learning

Cognitive ability is a key component in learning a language for children since it allows them to think about and judge information, thereafter, applying the knowledge gained in various situations. According to the National Education Agency [16], cognitive ability is expressed through learning as well as critical and problem-solving thinking, essential in the context of teaching a language. Kids who can grasp and explain texts can use language skills in a hands-on way within the needs of that text.

Studies have indicated that manual and active activities, which enhance the linguistic labour of children, help in the development of reasoning abilities. According to Cremin et al. [5], the use of storytelling and acting techniques by children helps them understand causal relationships so that the child structures their thoughts and can put them into purposeful expression. Playing and storytelling make children more expressive linguistically [18], but also enhance the development of critical thinking, since children must analyse the structure of stories and the behaviour presented by the characters along with the decisions made.

The National Education Agency's Framework for pre-primary Education [16] provides a mapping between cognitive competence and language learning achievements, showing how these competences are integrated in practice (see Table 2).

TABLE 2 COGNITIVE COMPETENCE COHERENCE IN LANGUAGE EDUCATION

Cognitive competence	Language learning achievements
Knowledge and skills: understand and apply the structures of written language.	B2. Through play, observation and exploration, learns to read and write distinguishes letters from other signs and symbols, relates sound to letter; recognizes most letters of the alphabet; reads simple single words, notes, short sentences and multi-sentence easy-to-read and understand texts.
Critical thinking: analyses, evaluates and summarizes information and compares different points of view.	A3. Listens to short reading or narrative texts and discusses their content: clearly stated events (what happened?), time (when did it happen?), place (where did it happen?), identifies and briefly describes clearly identified characters

	in the text, identifies a clearly stated theme (what is the text about?).
Problem solving explore, analyses and solve linguistic challenges through practical activities.	B1. Explores and experiments with language by playing a variety of language games, asking questions, searching for information in sources of his/her own choice or suggested sources (books, internet, etc.).
Learning: assessing your own performance, learning from mistakes, reflecting on decision-making.	A2. Listening to others, expresses his/her own opinion and listens to others' opinions, describes the course of a planned activity, the outcome, responds to others' questions, requests, observations, clarifications, asks for a repetition if he/she has not understood something, applies some rules of language etiquette: greeting, farewell, thanking, etc.

Compiled according to the pre-primary Framework [16]

New methods like digital storytelling can also aid in improving the cognitive capacity of children. As per the research conducted by O'Byrne et al. [19], creating digital content can advance language development in children, fostering critical thinking. This result aligns with the findings of Kervin and Mantei [12], as new interactive technologies provide children with opportunities to learn the intricacies of language and express their thoughts and ideas.

Problem-solving skills play a crucial role in language activities since children advance in cognitive proficiency through mastery of language. As emphasized by Jankūnaitė and Bagdonas [8], a play-based approach offers opportunities to test language, which supposedly makes children more logical and thoughtful individuals. Kazakevičiūtė et al. [11] point out that the competence in critical thinking since early age ensures the possibility of linguistic expression, sets conditions for generating adequate judgments, and requires an evaluation of information while building logically structured arguments.

To sum up the entire consideration of injecting thinking skills into itself forms a fundamental ultimate core on development both cognitively and linguistically in children. The evidence indicates that interactive activities, digital technologies, and play-based methods help children improve their analysis of problems, developing problem-solving skills as well as reflection on their own learning. It is this process that makes them acquire language structures as an instrument rather than mere product, which facilitates an entire general cognitive and academic social ad healthy competency appropriate to healthy development.

Creativity is one of the most important factors in language teaching because through it children not only reach a high linguistic level but also develop abilities of self-expression as well as start original thinking and innovation, be it in problem-solving. In the words of the National Education Agency [16], creativity is born in the very process of linguistic activities of children as an ability to generate ideas, look for solutions, and experiment with

language. and creative competence supports linguistic variation and allows the expression of ideas with various degrees of freedom through meaningful narratives.

Research reveals that creative capacities are most closely associated with proficiencies in two principal genres: storytelling and acting. Participation in creating stories and narrating them to others allows children not only to attain concepts but also to develop their imaginative and innovative thinking as stated by Cremin et al. [5]. Nicolopoulou et al. [18] similarly suggest that these types of activities make children more inventive in adopting linguistic forms and codes to tell stories while improving their social and emotional stratagems.

The National Education Agency's Framework for pre-primary Education [16] provides a mapping between the competences of creativity and achievements in language education, illustrating how these competences are integrated in practice (see Table 3).

TABLE 3 COHERENCE BETWEEN CREATIVITY COMPETENCE AND LANGUAGE EDUCATION ACHIEVEMENT

Creativity competence	Language learning achievements
Exploration: identifies problems and creative opportunities; gathers, relates and critically evaluates information for creative work; shares knowledge, ideas and experiences.	B1. Explores and experiments with language by playing a variety of language games, asking questions, searching for information in sources of his/her own choice or suggested sources (books, internet, etc.).
Exploration: identifies problems and creative opportunities; gathers, relates and critically evaluates information for creative work; shares knowledge, ideas and experiences.	B1. Explores and experiments with language by playing a variety of language games, asking questions, searching for information in sources of his/her own choice or suggested sources (books, internet, etc.).
Generation: generates ideas, proposes solutions; chooses ideas that are meaningful to oneself and others and considers them from different perspectives.	A6. Playing with language, expanding vocabulary with new easy words. Usually it recognizes (guesses) the meaning of an unknown word based on context and/or own experience. Gives synonyms and antonyms for some words (without using terms) and begins to understand the figurative meaning of some frequently heard words.

Compiled according to the pre-primary Framework [16].

Digital tools play a crucial role in fostering creativity in language learning. According to Robin [21], digital storytelling provides children with an opportunity to create and visualize their own stories, as well as to reflect on the content and structure of their narratives. Various forms of interactive technology enable children to experiment with different modes of expression and channel their creative energy into linguistic activities [22].

Problem-solving ability is another aspect closely related to creativity. Leggett [13] notes that techniques used by educators to encourage children to explore and discover new ways of linguistic expression help them become better communicators and find innovative solutions in various scenarios. The play-based methodologies are very effective in the development of creative thinking since it enables children to experiment freely with language, spontaneously finding unexpected ideas.

Development of language and creativity in children will benefit greatly from having such abilities well integrated as time goes by, making them more unique and not mere copies of others. Development of language and creative gifts in children will draw much benefit from this ability when it gets well integrated over time and becomes more and more unique than mere copy. Research speak of the possibility for narrative modes, digital artifacts, and playing tools to act as rather potential accelerators in the development of creativity of thought and oral expression among children. Therefore, efforts must be oriented not only to find the ways enabling each child to find his creative side but also to find the ways enabling the child to find his unique linguistic personality.

B. Methodology of the research

A quantitative research approach was chosen for the study. Quantitative methods allow for mathematical evaluation and systematic analysis of data, as well as for establishing statistical relationships between variables [10].

B1. The study took place in six phases:

- In the first stage (February 2024), the analysis of scientific and methodological literature sources, documents regulating education allowed to reveal the relevance of the topic, to define the aim and objectives, and to formulate the problem of the research.
- In the second phase (March 2024), a test instrument was developed, empirically validated and tested to assess the cognitive and creativity competences of pre-primary children based on their language learning achievements (see Tables 1 to 3)
- In the third phase (April 2024), 42 pre-primary children, 21 boys and 21 girls, were recruited. Participants were selected from two schools in a Lithuanian city using availability sampling.
- In the fourth phase (May 2024), testing of pre-primary children took place in May 2024. The test was conducted based on the principles of voluntariness, privacy and confidentiality. All participants were informed about the objectives of the study, and their results were analysed anonymously [26]. Parents of the students were informed about the aims of the study and gave written consent for their children's participation in the study.
- In the fifth phase (August 2024), the analysis of the survey data was conducted. The collected data were

processed using statistical methods, ensuring accurate and reliable results. Descriptive and inferential statistical analysis was carried out to observe significant patterns and relationships within the data. Results obtained will be interpreted more deeply within the purview of a study related to cognitive and creative competences of children in early childhood education.

- This will be presented in Phase 6 that is results, synthesis, and discussion, and draws conclusions and methodological recommendations.

B2. Survey instrument

No instrument has been found to assess cognitive and creativity competences of pre-primary children based on their language learning achievements, so the second objective of the study was to develop such an instrument. It was decided to model a test (set of tasks) that would meet the following parameters (matrix): duration of the test (set of tasks) 90 min. The maximum score that pre-primary children could score was 14 points, 50% each of the cognitive and creativity competences, according to the pupils' basic level of achievement (see Table 4).

The test is based on the story "The Teddy Bear's Search for Friends," which explores the protagonist's quest to find friends in the forest and his encounters with various animals. The story enables children to grasp the meaning of the text, to analyse the sequence of events and to interpret the characters' actions and interactions.

The test consisted of eight items divided into two main groups according to competences:

- Cognitive competence tasks (1, 2, 3, 4.1-4.4) aim to develop children's critical thinking, problem-solving skills, learning and application skills. The tasks encourage children to analyse the text, to understand the relationships between the characters, to understand the sequence of events, to identify key information and to relate it to the narrative and moral message.
- The aim of the Creativity Competence Task (5) is to stimulate children's creativity and develop their ability to create stories, structure their thoughts and communicate ideas visually.

TABLE 4 TASKS FOR DEVELOPING COGNITIVE AND CREATIVITY COMPETENCES IN LANGUAGE EDUCATION

Task	Competence strand	Goal	Method of execution
1. What was the teddy bear looking for?	Critical thinking	Identify the main idea of the story.	The child must choose the correct answer from the answers given.
2. Where did the teddy bear look for friends?	Problem solving	Understand the context of the character's actions.	The child associates the organization's trip with the

			habitat and labels it correctly.
3. List in order what the teddy bear met on his journey.	The ability to learn	Developing the ability to reconstruct the sequence of events.	The child arranges the correct order of the characters' appearances from the given pictures.
4.1. Crossed-out word finds all the words written.	Subject knowledge and skills	Identify key information in the text and relate it to the questions.	The child looks for the words and labels them according to the colours indicated.
4.2 When did the teddy bear meet the hare?	Problem solving	Understand the time of the event and relate it to the story.	The child looks for the answer in the text and marks the correct time.
4.3 When did the teddy bear listen to animal stories?	Critical thinking	Understand the sequence of events and their significance.	The child marks the correct time in the story and links it to the action.
4.4 When did the teddy bear realise the importance of friendship?	The ability to learn	Link the moral message of the story to the character's experience.	The child decides the interpretation of the moment and writes the response.
5. Write out for the story of the other teddy bear's adventure in the woods and draw the picture on the paper given to represent it.	Development	Develop creative thinking, storytelling and visualization skills.	The child creates a new story, writes it down or tells it, and then illustrates it with a drawing.

B3. Reliability and validity

Reliability is one of the most important characteristics of qualitative research. Reliability refers to the trustworthiness of the instrument [29], the accuracy and stability of the measurements [30], and the internal consistency and constancy of the measurements [26]. The items were piloted before the test (item set) was developed. The process of piloting the items was intended to confirm the external validity of the test (item set), as it allowed us to see the typical errors made by pre-primary children. Each task and its assessment instructions were piloted in a group of 9 children, and 5 pre-primary teachers and 2 researchers were involved in the evaluation and reflection of the results and in the modelling of the competence of the task.

To test the internal consistency of the developed test/item set (the variables that make up the test scale),

Cronbach's Alpha was calculated to indicate the correlation between the test/item set and whether all the items in the test adequately represent the variable under study. The Cronbach's Alpha coefficient (0.763) indicates that the 8 variables of the test (item set) are consistent with each other, i.e. the scale of the test items is reliable as a measurement tool.

B4. General information about the test (set of items)

Statistical indicators for the test/item set were calculated using frequency analysis. Values such as mean, median, standard deviation, skewness, skewness, minimum and maximum values and percentile distribution were assessed (see Table 5).

TABLE 5 STATISTICAL INDICATORS OF THE RESULTS OF THE COGNITIVE AND CREATIVITY COMPETENCES TEST (SET OF TASKS) FOR PRE-PRIMARY CHILDREN

Parameters		Meanings
Mean		9,38
Median		9,00
Std. Deviation		2,197
Skewness		0,037
Kurtosis		-0,345
Minimum		5,00
Maximum		14,00
Percentiles	25	8,00
	50	9,00
	75	11,00

The analysis of the study results revealed that the mean (Mean) score of the children's test results was 9.00, while the median (Median) was also 9.00, indicating that most children scored close to the average value. This suggests that the children's performance was evenly distributed around the mean. The standard deviation (Std. Deviation) was 0.717, which implies that most children's results did not deviate significantly from the mean. This indicates a relatively homogeneous distribution of results with no extreme outliers. The skewness (Skewness) value was -0.345, indicating a slight leftward skew in the distribution. This suggests that more children achieved slightly higher scores than the mean, although this difference was not substantial. Kurtosis (0.037) indicates that the distribution approaches a normal curve. Therefore, the spread of results was not too peaked nor too flat; it has moderate variance performance.

The lowest recorded score (Minimum) was 5, while the highest (Maximum) was 14, showing that there were some differences in children's results, but extreme values were not frequent. Evaluating the percentile values, the 25th percentile (lower quartile) was 8.00, the 50th percentile (median) was 9.00, and the 75th percentile was 9.38. This suggests that most children scored between 8 and 10 points. In summary, the study's findings indicate that pre-

primary children's cognitive and creativity competency test results were relatively evenly distributed, with most children performing around the mean. The slight negative skewness suggests that a higher proportion of children obtained above-average scores, while the standard deviation reflects a moderate spread of results without significant variation.

Looking at the histogram of the distribution of the scores of the pre-primary children who took the test (set of items) (see Figure 1), it can be assumed that the distribution follows a normal distribution.

To test the hypothesis of normality of the distribution of the test scores, the Shapiro- Wilk test was used.

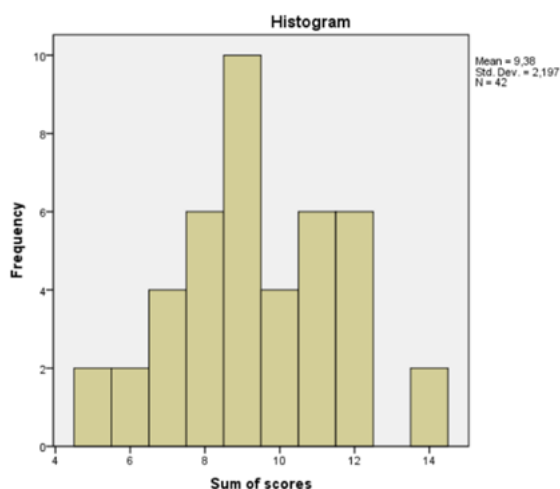


Fig. 1. Histogram of test score distribution among preschool children.

The test/task set scores of the 42 children who completed the test/task set were found to follow a normal distribution ($W(42) = 0.969$, $p = 0.279$). Coefficient of asymmetry (0.037); coefficient of excess (-0.345). The coefficient of internal consistency (Cronbach's Alpha 76.3%) indicates that the test is appropriate.

B5. Research ethics

The study adhered to the guiding principles of the *European Code of Conduct for Research Ethics* [15].

1. Reliability - used to ensure the quality of research in terms of design, methods, analysis and use of resources.
2. Integrity - applies to the transparent, fair, complete and impartial preparation, conduct and verification of studies and reports.
3. Respect for colleagues, research participants, society, ecosystems, cultural heritage and the environment.
4. Responsibility for research, from conception to publication, management and organisation, training, guidance, advice and wider influence.
5. To ensure anonymity, only aggregated data is published and made public, and information obtained during the study is used only for its intended purpose.

The author of the study has undertaken to publish only aggregated data from the study.

The Principles of Research Ethics require that students' participation in research is voluntary. Participants were informed that they could withdraw from the study at any time they wished and would not be subject to any pressure if they did so. However, to avoid attrition, regular contact was maintained with the participating pupils and their parents. According to [15] the data collection procedure may cause anxiety for the participants because of its unusual and novel nature. With this threat in mind, the researchers reassured the participants before data collection began by providing them with as much information as possible about the data collection procedure and by pre-emptively allaying any anxieties about the data collection.

III. RESULTS AND DISCUSSION

Distribution of Cognitive and Creativity Competency Results by Gender

This study aimed to analyse the distribution of cognitive and creativity competencies among preschool children (5-6 years old) based on gender. A total of 21 girls and 21 boys participated in the study (see table 6).

TABLE 6 DISTRIBUTION OF PRESCHOOL CHILDREN'S COGNITIVE AND CREATIVITY COMPETENCY TEST RESULTS BY GENDER

Gender	Girl	Boy
N	21	21
Mean	9,24	9,52
Std. Deviation	2,047	2,379
Skewness	1,036	-0648
Kurtosis	1,196	-0,732
Percentiles 25	8	8
Percentiles 50 (Median)	9	9
Percentiles 75	10	12

The results showed that the mean test score for girls was 9.24, while for boys, it was 9.52, indicating that both genders achieved relatively similar scores. The median value was 9.00 for both groups, suggesting that most children obtained scores close to this value. The standard deviation for girls was 2.047, whereas for boys, it was 2.379, showing that boys' results had a slightly wider distribution, meaning their scores varied more than those of the girls. The skewness value for girls was 1.196, while for boys, it was -0.732 , indicating that boys' scores were slightly skewed towards lower results, whereas girls' scores showed a tendency towards higher values. The kurtosis value for boys was -0.648 , while for girls, it was

1.036, suggesting that the distribution of girls' scores was more peaked, whereas the boys' distribution was more spread out. The lowest score among girls was 6, and the highest was 14, while boys' scores ranged from 5 to 12. Examining the percentiles, the 25th percentile for girls was 8.00, the 50th percentile (median) was 9.00, and the 75th percentile was 9.52, indicating that most girls scored between 8 and 10 points. Among boys, the 25th percentile was 8.00, the median was 9.00, and the 75th percentile was 9.24, showing a similar pattern.

Thus, the mean results were almost equal for the girls and boys. The girls' achievements leaned more towards high values since the boys' results had wider dispersion. More individual variability among boys was indicated by wider spread of scores around similar mean scores for both genders. Such cognitive and creative abilities development might be dependent on the individual style of learning itself and the methods of education applied as a process of learning affecting boys and girls in different ways.

Cognitive and Creativity Competency Results This study set out to carry an analysis of the distribution of cognitive and creativity competencies present among preschool children.

The aim was to analyse the test results of pre-primary children on Cognitive competence and Creativity competence. Descriptive statistical approaches were used in the analysis, presenting mean (Mean), median (Median), standard deviation (Std. Deviation), skewness (Skewness), kurtosis (Kurtosis), minimum-maximum values (Minimum, Maximum), and percentiles (Percentiles) (see table 7).

TABLE 7 DISTRIBUTION OF PRESCHOOL CHILDREN'S COGNITIVE AND CREATIVITY COMPETENCY RESULTS

		Cognitive competence	Creativity competence
Mean		4,86	4,52
Median		5,00	5,00
Std. Deviation		1,983	1,452
Skewness		-,305	-,300
Kurtosis		-1,359	-,467
Minimum		1	2
Maximum		7	7
Percentiles	25	3,00	3,75
	50	5,00	5,00
	75	7,00	5,00

The results indicated that cognitive competency scores were slightly higher than creativity competency scores, but the difference was not significant. The mean cognitive competency score was 4.86, while the mean creativity competency score was 4.52, suggesting that cognitive skills were marginally more developed. The median for

both competencies was 5.00, indicating that most children achieved a mid-range score.

The standard deviation for cognitive competencies was 1.983, whereas for creativity, it was 1.452, revealing that cognitive competency scores were more widely dispersed, while creativity competency scores were more concentrated around the mean. The skewness value for cognitive competencies was -1.359, while for creativity, it was -0.467, suggesting that cognitive scores tended to be skewed towards higher values, while creativity scores were more evenly distributed.

The kurtosis values for cognitive and creativity competencies were -0.305 and -0.300, respectively, indicating a nearly normal distribution. However, cognitive competency scores exhibited a slightly flatter distribution, whereas creativity scores were more clustered around the mean. The minimum score for both competencies was 2, and the maximum was 7, demonstrating that all participants reached a certain level of competency. In terms of percentiles, the 25th percentile for cognitive competency was 3.00, the 50th percentile (median) was 5.00, and the 75th percentile was 5.00, showing that most children scored between 4 and 5. The same distribution was observed in creativity competency scores, with a 25th percentile of 3.00, a median of 5.00, and a 75th percentile of 5.00.

In summary, the study found that cognitive competencies were slightly more developed than creativity competencies, but the difference was minimal. Scores in the cognitive competency were widely distributed whereas in the creativity competency, they were more concentrated around the median. It implies that, perhaps, formulaic creativity must be given more attention in the learning process to effectively balance the development of both competencies.

A paired samples t-test was conducted to determine whether the difference between the two competencies was statistically significant. The analysis yielded a mean difference of 0.333 with a standard deviation of 2.693 and a standard error of 0.16. The 95% confidence interval for the mean difference ranged from 0.506 to 1.173, and the two-tailed significance value ($p = 0.427$) exceeded the conventional threshold of 0.05. These findings indicate that the observed difference in means is not statistically significant, suggesting that there is no strong evidence to support a meaningful disparity between cognitive and creativity competencies in this dataset.

The results imply that while cognitive competence appears slightly higher than creativity competence on average, the lack of statistical significance suggests that the two competencies are relatively balanced in the given sample. The very low correlation between them, therefore, further confirms that cognitive development does not always go along with an equal increase in creativity. These perspectives drive home the need for equipping educational and developmental initiatives with cognitive and creative capabilities rather than concentrating on one. Subsequent research could look into other drivers of these

capabilities – maybe, environmental factors, pedagogical factors, and/or sociocultural factors – for a fuller picture of their dynamics.

Analysis of Preschool Children's Cognitive Competencies

The cognitive competency of preschool children was evaluated using a language-based assessment consideration. These are some problem-solving or learning to learn components critical thinking-based cognitions and creativity competencies among preschool children aged five to six years.

TABLE 8 PRESCHOOL CHILDREN'S COGNITIVE COMPETENCY RESULTS

	Critical thinking	Problem solving	Learning to learn
Mean	1,33	1,43	1,33
Median	1,00	2,00	1,00
Std. Deviation	,570	,801	,650
Skewness	–,123	–,953	–,455
Kurtosis	–,622	–,735	–,635

Statistical analysis was conducted to determine the mean scores, standard deviations, medians, minimum and maximum values. The data were analysed using descriptive statistical methods.

The statistical analysis revealed that the highest results were observed in the Problem-Solving competency, where the mean score was 1.43, with a standard deviation of 0.801. This indicates that children's ability to solve problems was the most developed among the assessed competencies, though the higher standard deviation suggests a significant variation in individual results. The Critical Thinking competency had a mean score of 1.33 and a standard deviation of 0.570. Although the mean was slightly lower than for Problem Solving, the lower standard deviation suggests that the results were more evenly distributed among all participants. The lowest median score (0.63) was observed in this category, indicating that a significant portion of the children scored lower, although some achieved higher results.

The Learning to Learn competency also had a mean score of 1.33, but with a standard deviation of 0.650, indicating a broader distribution of results compared to Critical Thinking. The minimum score in this category was 1.00, while the maximum was 1.48, suggesting a relatively narrow range of achievements among the children. However, the mean value indicates that the learning ability was well developed.

In brief, the Problem-Solving skill stood as the strongest amid the checked youngsters, while Critical Thinking and Learning to Learn revealed akin average tallies though with dissimilar spreads. This indicates that nursery schooling ought to focus on improving critical thinking and learning aptitudes to ensure more even

competency growth and lessen the disparity between the top and bottom students.

Analysis of the Interrelations Between Children's Cognitive Competencies

This study aimed to determine the intercorrelation among the cognitive competencies of preschool children, namely Subject Knowledge and Skills, Critical Thinking, Problem-solving, and Learning to Learn, as shown in Table 9.

TABLE 9 SPEARMAN'S RANK CORRELATION COEFFICIENTS BETWEEN COGNITIVE COMPETENCIES

Spearman's Correlations					
		Subject knowledge and skills	Critical thinking	Problem solving	Learning to learn
Subject knowledge and skills	Correlation Coefficient	1	,508**	,565**	,481**
	Sig. (2-tailed)	.	0,001	0	0,001
Critical thinking	Correlation Coefficient	,508**	1	,645**	,673**
	Sig. (2-tailed)	0,001	.	0	0
Problem solving	Correlation Coefficient	,565**	,645**	1	,573**
	Sig. (2-tailed)	0	0	.	0
Learning to learn	Correlation Coefficient	,481**	,673**	,573**	1
	Sig. (2-tailed)	0,001	0	0	.

** . Correlation is significant at the 0.01 level (2-tailed).

To test the hypothesis regarding the normality of the distribution of cognitive competency achievements among the study sample, the Shapiro-Wilk test was used. It was determined that the data do not follow a normal distribution ($p < 0.05$).

Since the Shapiro-Wilk test indicated that the data do not follow a normal distribution ($p < 0.05$), the Spearman rank correlation coefficient was chosen for further correlation analysis. This method is appropriate when data do not meet normality assumptions, as it assesses monotonic relationships between variables rather than linear ones.

The correlation table reveals that all four cognitive competency components exhibit statistically significant positive correlations ($p < 0.01$), indicating that children's achievements in one competency are associated with their performance in others. The strongest correlation was found between Critical Thinking and Learning to Learn ($r = 0.673$), suggesting that stronger critical thinking skills are closely linked to better learning-to-learn abilities. A high correlation between Problem Solving and Critical Thinking was found, namely 0.645, which means that there is a strong relationship between these two skills

children who are good at puzzle solving usually have good critical thinking skills.

A good correlation resulted between Subject Knowledge and Skills and Problem Solving ($r = 0.565$), indicating that if a student has better knowledge and skill regarding the subject, they will be able to solve problems more effectively. The weakest but still significant correlation has been observed between Subject Knowledge and Skills and Learning to Learn ($r = 0.481$), suggesting that while Problem Solving and Learning to Learn might be related, their relationship tends to be weaker than some other analysed pairs.

In brief, cognitive competency compartments of children are closely interrelated. Therefore, enhancing one of these competencies may positively affect the others. The most explicit relationship was between Critical Thinking and Learning to Learn, showing that analysing information and making an inference is a component part of learning. For that reason, educational programs must cultivate these sorts of qualities as related skills capable of having long-term impacts on the learning success of children.

IV. CONCLUSIONS AND DISCUSSION

The language results confirmed that preschool children's cognitive and creative abilities were related to language achievement, which echoed the results of previous research on the role of language in shaping children's thinking process and creativity [18], [5]. Tests of text analysis, narrative construction, and problem-solving language tasks showed that most children had average or better abilities. The pattern of results shows that there is no statistically significant difference between boys and girls in cognitive and creative abilities. The distribution of results for boys is more scattered, while girls are more clustered around the mean, which indicates that the learning process may differ by gender [11]. Also, it was seen that kids with good language did well in both smart and creative jobs. This backs the idea between speaking well and growing thoughts [16].

The used tool proved to be reliable in objectively testing children's cognitive and creative abilities. The achieved results showed an even distribution of children's achievements. She also agreed with the previous observation that there are no systematic methodological norms, which hinders the control and monitoring of these abilities in the educational system. This conclusion confirms similar statements of previous studies that there is no clear methodology and tool that pedagogues can use to systematically monitor the development of children's creative and cognitive abilities [8].

Earlier, the factors of language development and creativity development were considered. According to research, "Story and play-based activities foster children's creative thinking and shape their minds" [18], [5]. Other studies have shown that "Digital storytelling technologies can help teachers more effectively promote children's language and cognitive abilities" [21], [19]. This study

also reveals that conventional assessment tools may not be suitable for measuring a child's creative and cognitive dynamics, so new assessment tools need to be sought.

Based on the research, it can be recommended to increase the implementation of interactive and digital teaching tools in the preschool education system, as previous studies have proven that the methods are effective enough to promote children's creative expression and critical thinking [22], [12]. Secondly, the training of pedagogues in the field of creative and cognitive education should be improved, because structural methods can be used to better monitor and develop children's abilities. The created criteria for evaluating creativity and critical thinking would allow not only to better reveal the development of these abilities in children but also ensure the process of individualization in studies [8], [16].

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Teaching Linear Regression with Python and Excel: Methods, Tools, and Practical Tasks

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Abstract— This article analyses various approaches to teaching linear regression using Python and Excel. The inductive and deductive methods, as well as problem-based learning, are examined. Examples of using the scikit-learn library or Excel functionalities for building linear regression models are described. Practical tasks are presented to support the understanding of regression analysis concepts.

Keywords— Excel, linear regression, Python, teaching methods.

I. INTRODUCTION

Linear regression is a fundamental statistical method widely applied in various fields such as economics, engineering, social sciences, medicine, and data analysis. Understanding this method is essential for students studying data analysis and machine learning.

Various pedagogical methods can be used in teaching linear regression, encouraging analytical thinking and the application of mathematical models. The main approaches include:

a) Deductive method – concepts are presented theoretically and then applied to examples [1]. Deduction starts with general principles and concludes with specifics [2], working in a “top-down” direction, from theory to data that may support or contradict the theory [3].

b) Inductive method – students derive relationships through the analysis of specific examples [1]. Induction involves moving from specifics to general conclusions [2],

following a “bottom-up” direction by using participants' insights to develop broader themes [3].

Researchers suggest combining both methods, as successful learning requires integrating inductive and deductive approaches for better comprehension [4], [5].

c) Problem-based learning (PBL) – students work on real-world tasks, explore data, and formulate hypotheses [6]. The goal of this type of learning is long-term knowledge retention and the development of practical skills for applying knowledge in real situations [7].

Python and Excel are widely used tools for data analysis. Python offers libraries such as NumPy and SciPy for data processing, while Excel provides built-in functions for statistical analysis. Scikit-learn enables the construction of regression models, whereas Excel uses the "Data Analysis ToolPak" for regression analysis.

This article aims to analyse the effectiveness of different methods for teaching linear regression and to propose approaches for integrating them into the learning process. By combining the analytical power of Python with the structured approach of Excel, teaching becomes more interactive and accessible to students with varying levels of preparation.

II. MATERIALS AND METHODS

The deductive method is particularly useful in the early stages of learning, where students need to acquire fundamental knowledge, while the inductive method is

Online ISSN 2256-070X

<https://doi.org/10.17770/etr2025vol3.8556>

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successfully applied to develop critical thinking when working with real data.

A. Deductive Method

The deductive method starts with presenting the theoretical foundations of linear regression, followed by practical application. The main stages include:

- Explaining the linear regression equation (1);

$$\hat{y} = a + bx \quad (1)$$
- Defining the least squares method;
- Using Python and Excel to apply the model to real data.

This method is beneficial for students who prefer a systematic approach to mathematical concepts.

B. Inductive Method

The inductive method works by analysing real-world examples from which students independently identify patterns. In the context of linear regression, this approach can be implemented through:

- Providing a dataset on sales and advertising;
- Visualizing the data using scatter plots;
- Discussing potential relationships between variables.

The goal of this method is for students to conclude that a linear relationship exists between variables, which can be modelled using a regression equation.

C. Problem-Based Learning

Problem-based learning places students in a situation where they must independently analyse data and build a regression model. For example:

- Providing data on shopping mall attendance based on temperature;
- Students constructing a regression model and analysing the obtained results;
- Discussing additional factors that may influence attendance.

This method fosters analytical skills and encourages independent thinking.

III. RESULTS AND DISCUSSION

A. Building a Linear Regression Model in Microsoft Excel

Teaching linear regression begins with a deductive approach, where students first learn theoretical concepts and then apply them in practical tasks using Excel. This method ensures structured presentation but carries the risk of passive knowledge absorption. To increase student engagement, practical examples are introduced after the theoretical material. These examples are made available in a shared online file, facilitating independent task execution and encouraging the application of acquired knowledge.

Task 1: The table below presents data on the results of a Basic Programming 1 test and a Basic Programming 2 test for six students. Determine whether a relationship exists between the test scores. Create the following table in Excel. Construct a linear regression model. Generate a graph of

the data. Make a prediction for the Basic Programming 2 test result if a student scores 70 on the Basic Programming 1 test.

TABLE I TEST SCORES COMPARISON

Student	Programming Test Scores	
	Basic Programming 1 Test (X)	Basic Programming 2 Test (Y)
A	75	78
B	100	95
C	66	64
D	50	40
E	88	80
F	20	40
G	55	50
H	95	90
I	73	76
J	82	85

To successfully complete this task, students should have basic knowledge of Excel.

The steps for completing the task involve:

- Creating a data table;
- Calculating the mean for each column;
- Computing the coefficients a and b ;
- Formulating the regression equation;
- Predicting the Basic Programming 2 test score for $X = 70$ by substituting it into the regression equation;
- Creating a scatter plot via Insert → Scatter;
- Adding a trendline by selecting Add Trendline;
- Enabling Display Equation on Chart and Display R-squared value on Chart.
- Expected result: learners should obtain the following graph (Fig. 1):

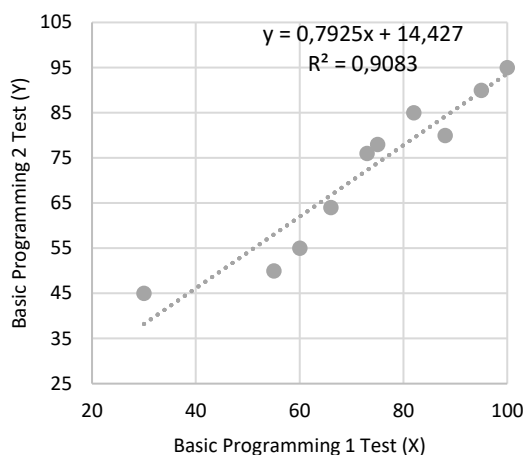


Fig. 1. Linear regression model of the test results.

After constructing the regression equation, students compare the manually calculated values of coefficients a and b with the automatically generated equation in Excel. Any differences (if present) are analysed, with a particular focus on predicting the Basic Programming 2 test score for $X = 70$.

Task 2: Table II presents data on the average temperature and precipitation levels for each month of the year. The objective is to determine how temperature influences precipitation and to construct a regression model using Excel's Regression tool.

TABLE II MONTHLY AVERAGE TEMPERATURE AND PRECIPITATION

Month	Climatic Indicators	
	Average Temperature (°C)	Precipitation (mm)
January	-2.5	42.2
February	-3	25.4
March	5.5	52.2
April	10.7	58.4
May	19.5	65.2
June	24	68.3
July	28.8	70.2
August	26.5	65.7
September	18.2	60.8
October	9.8	61.2
November	2.3	45.9
December	1.2	46.4

Steps for Completing the Task:

- Create a data table containing temperature and precipitation values.
- Open the "Data Analysis" tool from the "Data" menu in Excel.
- Select "Regression" from the available analysis tools.
- Set Input Y Range (dependent variable) and Input X Range (independent variable).
- Enable "Line Fit Plots" to generate a graph of the linear relationship.

Once the task is completed, the regression analysis results should be examined. An inductive approach is applied in this case, where students first work on the problem and then discuss the expected results, with theoretical concepts introduced as needed to aid in the analysis.

After processing the data, the generated output tables are analysed. The Summary Output provides an overview of the regression results, while the ANOVA table presents key indicators such as degrees of freedom, regression sum of squares, residual sum of squares, null hypothesis (H_0), alternative hypothesis (H_1), t-statistic, confidence intervals, intercept, and regression coefficients. The Residual Output contains residual values, showing the differences between predicted and actual values.

Finally, the generated graph illustrating the linear dependence between the dependent and independent variable is examined.

B. Building a Linear Regression Model in Python

In a follow-up lesson, problem-based learning (PBL) can be applied, encouraging students to discover solutions through analysis. A shared file containing predefined tasks is provided to students in an online learning environment.

Task 3: Table III presents real estate price data in euros based on property area in square meters.

TABLE III REAL ESTATE PRICES BASED ON PROPERTY AREA

Property	Real Estate Characteristics	
	Area (m ²)	Price (€)
Property 1	70	129,000
Property 2	45	80,000
Property 3	90	165,000
Property 4	100	190,000
Property 5	55	105,000
Property 6	85	150,000
Property 7	60	110,000
Property 8	120	225,000
Property 9	95	175,000

Property	Real Estate Characteristics	
	Area (m ²)	Price (€)
Property 10	50	95,000
Property 11	110	205,000
Property 12	130	250,000
Property 13	75	135,000
Property 14	65	122,000
Property 15	80	140,000

Based on the data in Table III, construct a linear regression model in Python. Calculate the coefficient of determination (R^2). Determine the regression parameters—slope and intercept. Plot the regression line and predict the price of a property with an area of 75 square meters.

Task 4: Table IV provides data on the number of visitors to a shopping centre based on air temperature over several days. The aim is to examine the relationship between temperature and customer visits. Based on the data, build a linear regression model and use it to predict the number of visitors when the temperature is 14 °C.

TABLE IV CUSTOMER VISITS BASED ON TEMPERATURE

Day of the Month	Table Column Head	
	Temperature (°C) (X)	Number of Customers (Y)
1	6	52
2	8	54
3	10	66
4	8	60
5	22	98
6	18	80
7	15	72
8	12	65
9	25	110
10	5	48

Task 5: Table V presents data on the time customers spend in a store and the amount spent. Build a linear regression model in Python. Calculate the coefficient of determination. Extract the regression parameters—slope and intercept. Plot the regression line. Predict the spending for a customer who spends 12 minutes in the store.

TABLE V TIME SPENT IN STORE VS. AMOUNT SPENT

Record	Customer Purchase Data	
	Time Spent in Store (minutes)	Amount Spent (€)
1	5	8
2	7	10
3	10	13
4	15	18
5	20	22
6	25	25
7	30	30
8	35	35
9	40	42
10	45	48

To successfully complete these tasks, students should have basic knowledge of Python programming. They receive instructions for independent exploration of the scikit-learn library [8] and its key linear regression classes, while the instructor facilitates the process by guiding discussions and asking targeted questions.

In this lesson, the instructor acts as a facilitator rather than a direct source of knowledge, aiming to develop students' lifelong learning skills [6].

The steps for completing the task require:

- Importing the scikit-learn library
- `from sklearn.linear_model import LinearRegression`
- Creating a model of type LinearRegression
`model = LinearRegression()`
- Training the model using the fit() method, where X contains the independent variables and y is the dependent variable:
- `model.fit(X, y)`
Predicting new values with the predict() method:
`predictions = model.predict(X_new)`
- Evaluating the model's quality using the score() method
`score = model.score(X, y)`

After completing each task, students analyse the obtained coefficients, the regression line, and the coefficient of determination values. At the end of the lesson, a discussion is held on the applications of linear regression in the real world, emphasizing the importance of this method for forecasting and data analysis.

IV. CONCLUSION

The use of Python and Excel in teaching linear regression provides an effective approach for introducing students to regression analysis. Excel is a convenient tool for quick analysis and visualization, while Python offers

greater flexibility and automation. By combining the inductive and deductive methods, along with problem-based learning, the teaching process becomes more effective and engaging. Future lessons may expand to include topics such as multiple, polynomial, and logistic regression, with Python and Excel continuing to support deeper understanding and real-world data analysis.

ACKNOWLEDGMENTS

This work was supported by the Technical University of Varna.

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The Potential of Sketchfab in Visualizing Technical Processes in the Educational Environment

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Abstract—This paper explores the potential of Sketchfab as a tool for visualizing technical processes in the educational environment, focusing on its application in STEM and technology education. The research examines how the platform's 3D modeling and visualization capabilities can enhance learning outcomes by fostering a better understanding of complex technical concepts and improving spatial reasoning. The study is grounded in the context of the increasing digitalization of education and the integration of immersive technologies in teaching practices. The research employs a mixed-methods approach, combining quantitative analysis of user engagement statistics with qualitative interviews and surveys conducted with both teachers and students. Statistical data were collected on the number of users, their purposes for using Sketchfab, and the time spent engaging with the platform. Additionally, perceptions of Sketchfab's impact on learning outcomes were assessed, focusing on its role in enhancing student motivation, improving understanding of technical content, and developing spatial thinking. Results indicate a significant increase in the adoption of Sketchfab among educators and learners between 2023 and 2024, with teacher usage rising by 40% and student engagement growing by 37.5%. The platform is primarily utilized for visualizing 3D models, facilitating project-based learning, and enhancing laboratory work. Students reported a high level of satisfaction, with 85% agreeing that Sketchfab improved their understanding of complex subjects and 90% indicating

that it contributed to the development of their spatial thinking. The findings suggest that Sketchfab offers valuable pedagogical benefits, particularly in technical and STEM education. By providing an interactive, immersive learning experience, it enables students to visualize abstract concepts and engage in hands-on learning, thus supporting constructivist approaches to education. The platform's integration into instructional design not only enriches content delivery but also fosters a student-centered learning environment. In conclusion, Sketchfab represents a promising tool for the visualization of technical processes in education. However, its full potential requires further exploration through long-term studies and the development of methodological guidelines for its effective use in various educational settings. Recommendations for educators include incorporating 3D modeling as a central element in project-based learning and utilizing Sketchfab to facilitate collaborative problem-solving tasks.

Keywords— *Sketchfab, 3D visualization, technical processes, educational technology.*

I. INTRODUCTION

In the modern educational environment, significant attention is being paid to the integration of advanced digital technologies, particularly virtual 3D models, to enhance the quality of the learning process. One such tool

Online ISSN 2256-070X

<https://doi.org/10.17770/etr2025vol3.8517>

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is Sketchfab — a platform for creating and viewing 3D models online, which has the potential to fundamentally change the approach to visualizing technical processes in educational institutions [1]. Specifically, Sketchfab offers opportunities for more visual and interactive learning, which is crucial in the context of technical education.

Given the martial law situation in Ukraine and the significant challenges faced by the educational process, virtual technologies have become especially relevant [2]. They allow for the continuity of education by providing access to modern educational resources, even with limited physical interaction and resources [3]. In particular, Sketchfab can serve as a powerful tool for studying technical disciplines, as the platform enables the modeling and visualization of complex technical processes, thereby promoting a deeper understanding of both theoretical and practical aspects of the learning material [4].

The relevance of this study lies in the need to adapt the educational process to new realities, especially in conditions where traditional teaching methods may be complicated due to restrictions imposed by military actions [5]. Considering the specifics of using such technologies for visualizing technical processes will increase learning effectiveness and maintain a high level of educational standards, even under extraordinary circumstances [3].

Research conducted by scholars analyzing alternative platforms confirms that traditional tools such as Autodesk Fusion 360, Blender, and Unity, while offering advanced modeling and simulation capabilities, often require high computational resources, which can hinder their application in contexts with limited access to powerful hardware [7]-[8]. Given the current challenges in digital education, particularly in regions affected by crises, the accessibility and adaptability of educational technologies play a crucial role in ensuring uninterrupted learning.

International educational institutions have demonstrated that web-based platforms with integrated collaborative functionalities and mobile adaptability are the most effective solutions during periods of educational disruption [9]. Unlike desktop-based modeling software, which may present technical barriers due to installation requirements and hardware dependency, Sketchfab provides a scalable, user-friendly, and cloud-based alternative that facilitates seamless access to 3D visualization tools across multiple devices.

From a pedagogical perspective, Sketchfab aligns with modern constructivist approaches by supporting interactive, experiential, and competency-based learning [10]. The platform enables real-time collaboration, fostering student engagement, problem-solving skills, and spatial cognition—key competencies in STEM and technical education. Moreover, its intuitive interface and cross-platform compatibility make it an ideal tool for blended learning environments, allowing both educators and learners to engage with immersive educational content without technical constraints [11].

Thus, the aim of this article is to explore the potential of using Sketchfab to visualize technical processes in the educational environment, taking into account the challenges arising from the martial law situation in Ukraine.

To develop modern education in Ukraine, it is important not only to conduct theoretical research but also to implement practical studies that promote the activation of independent, creative, and innovative thinking among engineers. The use of innovative technologies such as 3D modeling in the educational process, when applied correctly, allows for the significant expansion of engineers' worldviews, enhances their cognitive activity, and contributes to the formation of general scientific competencies [14]. Specifically, the application of the Sketchfab program for visualizing technical processes enables engineers to study object modeling and create interactive 3D models at different training stages. However, there is still a need to improve the educational and methodological support that would facilitate the effective integration of this tool into the educational process [17]. The aim of this article is to analyze the possibilities of using the Sketchfab program for teaching the creation of 3D models of various objects and to highlight existing problems and potential solutions for ensuring high-quality training in the educational environment of Ukraine.

II. MATERIALS AND METHODS

The research was conducted at Poltava State Agrarian University among students majoring in Agroengineering, within the framework of philological and engineering disciplines, and at Berdiansk State Pedagogical University in the context of teaching the courses «Fundamentals of Engineering and Pedagogical Creativity» and «Engineering and Computer Graphics». The aim of the study was to evaluate the pedagogical effectiveness of Sketchfab as an innovative digital tool for improving the visualisation of technical processes in engineering education. A mixed-methods research design was applied, combining quantitative analysis of user experience metrics with qualitative assessments of cognitive activity and didactic perception among students and teachers.

Various methods were used to collect data. The analysis of user engagement was based on the analytics of the Sketchfab platform. The study tracked user activity, session duration, and interaction with educational content during the 2023-2024 academic year. To evaluate the effectiveness of Sketchfab in improving technical visualisation, problem-based learning (PBL) and digital literacy, structured surveys were conducted among 150 students of the Agroengineering programme at Poltava State Agrarian University and 30 teachers from Poltava State Agrarian University, V. G. Korolenko Poltava National Pedagogical University and Berdiansk State Pedagogical University. Among them, 100 students and 20 teachers were from Poltava State Agrarian University, while 50 students and 10 teachers were from Berdyansk Pedagogical University. This distribution allowed for a comparative analysis of Sketchfab's effectiveness in

different educational contexts, considering both agricultural and pedagogical perspectives. Semi-structured interviews were also conducted with 20 students and 10 teachers from all three universities to gain a deeper understanding of the integration of 3D modelling tools into the curriculum and their impact on competency-based learning and cognitive development. The interviews were conducted in a guided discussion format (online via Zoom and in person at the universities), which allowed participants to discuss pre-defined topics and also provided an opportunity to express additional ideas. The questions focused on the effectiveness of Sketchfab in improving technical visualisation, problem-solving skills, spatial cognition, and its impact on student motivation and engagement.

Content analysis of the responses to the open-ended questionnaire and interview transcripts was conducted using thematic coding to identify recurring patterns and pedagogical insights.

A combination of descriptive and inferential statistics was used to process and analyse the data using SPSS software to examine learning outcomes. NVivo software was used for qualitative thematic analysis. The study followed a structured procedural design. The first stage was data collection, which took place from September 2023 to May 2024. During this stage, Sketchfab was actively used in laboratory and theoretical coursework. The next stage of data analysis (June-August 2024) included triangulation of the results to ensure validity and reliability, as well as to identify best practices for implementing 3D modelling technologies in agricultural engineering education.

A range of digital learning tools supported the study, including Sketchfab and online learning management systems (LMS). Surveys were distributed via Google Forms, and structured interview guides facilitated data collection. Theoretical analysis was conducted at Poltava V.G. Korolenko National Pedagogical University to contextualize the findings within broader trends of digitalization in education and the integration of immersive learning technologies. Primary statistical processing and data generalization were applied to analyze survey responses and engagement indicators, ensuring reliable and interpretable results.

III. RESULTS AND DISCUSSION

The role and significance of visualization technologies in the educational process were analyzed, along with the possibilities of studying 3D modeling in engineering education. The study also examined the specifics of modeling three-dimensional objects using the Sketchfab platform for visualizing technical processes in an educational environment, considering the state of martial law in Ukraine. The research is based on the analysis of current trends in digital technologies and their impact on the educational process, particularly on the development of technical competencies among engineers in conditions of limited resources and a challenging security situation.

To achieve the set objectives, a review of scientific works related to the use of 3D modeling and virtual reality in teaching technical disciplines was conducted. Special attention was given to studies that address the adaptation of educational processes during a military conflict and war. The research also included the practical implementation of virtual 3D models created on the Sketchfab platform in technical discipline classes for secondary school students and engineering students. The models featured technical processes, mechanisms, and technologies that demonstrate the practical application of theoretical knowledge.

A content analysis of materials on the Sketchfab platform was also carried out to assess their potential in the context of Ukrainian educational requirements and adaptation to the realities of martial law. The analysis included studying the available models, their quality, the presence of instructions, and their alignment with educational objectives. Furthermore, the effectiveness of traditional methods for teaching technical processes was compared with the use of digital 3D models, which helped identify the advantages and disadvantages of each approach under contemporary challenges.

Overall, the research methods allow for a deeper understanding of the potential of Sketchfab as a tool for visualizing complex technical processes in the educational environment and evaluating its significance in times of emergency and war, where it is crucial to maintain the quality of education even under resource constraints.

The first graph illustrates the growth dynamics of Sketchfab users in the educational sector from 2023 to 2024, categorized into teachers, students, and the total number of users (Fig.1.). The data indicate a significant increase in adoption, with the number of teachers using Sketchfab rising from 320 in 2023 to 450 in 2024, representing a 40% growth. Similarly, student engagement has increased from 1,200 to 1,650 users, reflecting a 37.5% rise. Overall, the total number of users has grown from 1,520 to 2,100, marking an increase of 38.2%.

This upward trend suggests a growing recognition of the pedagogical affordances of Sketchfab in enhancing digital literacy, facilitating immersive learning experiences, and fostering interdisciplinary approaches to education. The increased adoption among teachers highlights the platform's integration into instructional design, particularly in STEM education, where three-dimensional visualization aids cognitive load management and spatial reasoning development.

The significant rise in student engagement indicates a shift towards more interactive and constructivist learning paradigms, wherein learners actively explore, manipulate, and analyze 3D content to construct knowledge. This aligns with contemporary pedagogical frameworks emphasizing experiential learning, multimodal representations of information, and student-centered methodologies.

The growth in Sketchfab adoption may also be attributed to the increasing digitalization of education, the need for remote and blended learning solutions, and the rising demand for immersive educational technologies. These findings underscore the necessity for further research into the impact of 3D visualization tools on learning outcomes, as well as the development of best practices for their effective pedagogical integration.

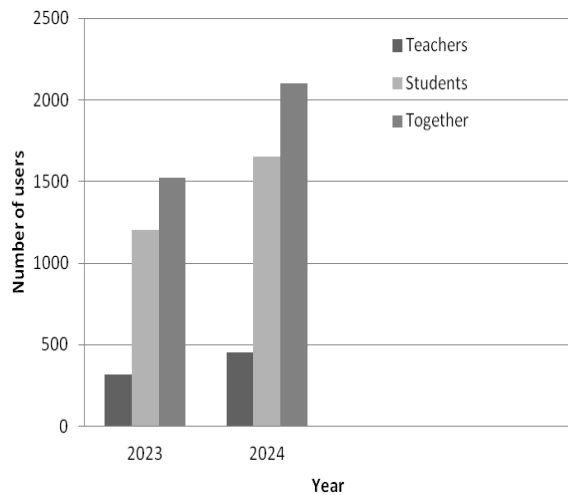


Fig. 1. Number of Sketchfab users among teachers and students.

The analysis of the obtained data indicates the widespread use of Sketchfab in the educational process, driven by its high potential for visualizing learning materials and enhancing project-based learning (Fig.2).

According to the results, the primary purpose of Sketchfab usage among educators is the visualization of 3D models (60%), highlighting a strong orientation of the educational process towards augmented and virtual reality technologies. This contributes to the development of both subject-specific and interdisciplinary competencies. The use of virtual models ensures the visualization of complex technical and scientific concepts, which is a crucial factor in facilitating their comprehension.

Among students, 3D model visualization also dominates (50%), yet they use the platform more frequently for project work (30%) compared to educators (20%). This trend aligns with modern requirements for developing project-based competencies and implementing inquiry-based learning methodologies.

Interestingly, students utilize Sketchfab for self-directed learning (15%) more often than educators (10%). This underscores the growing importance of self-regulated learning environments and reinforces the relevance of blended learning and flipped classroom methodologies.

The least common use of Sketchfab is for laboratory work (5% among students and 10% among educators). This may indicate that integrating 3D models into laboratory activities requires additional pedagogical scaffolding or specialized technical equipment.

Overall, the analyzed results confirm that the integration of digital tools, particularly Sketchfab, fosters the development of digital literacy, supports the implementation of STEM education principles, and enhances cognitive engagement through interactive learning methods. Optimizing pedagogical strategies with virtual technologies can improve the effectiveness of the learning process and align it with the demands of the modern educational environment.

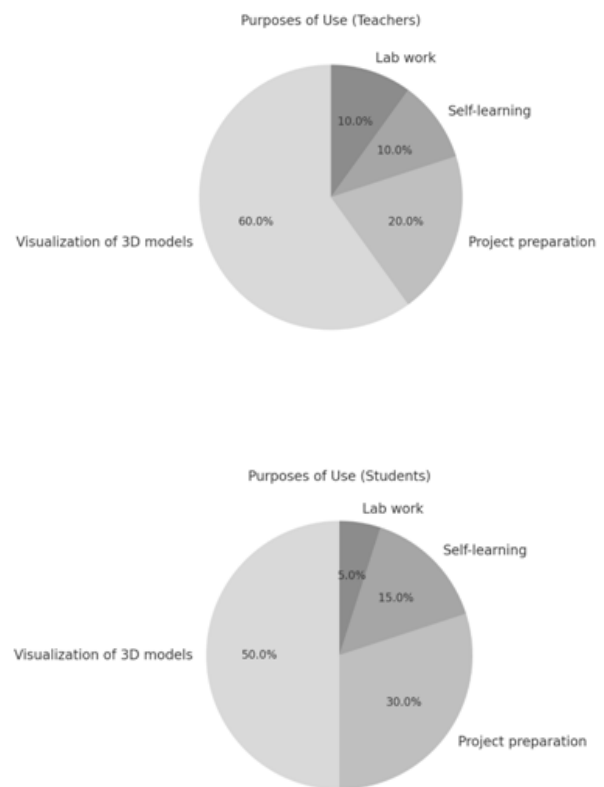


Fig. 2. Purpose of using Sketchfab in the learning process.

Research data indicate the active use of the platform by both instructors and students. The average time spent by instructors on Sketchfab is 3.5 hours per week, suggesting that they are integrating this platform into the learning process, particularly for visualizing and creating 3D models that can be applied across various subject areas. In contrast, students spend more time on Sketchfab (5.2 hours per week), which reflects high levels of interest and engagement in their learning activities. This level of engagement highlights the potential of this technology to foster cognitive skills, particularly spatial thinking, imagination, and independent learning. The overall average usage (4.3 hours per week) reflects a growing trend toward interactive learning, which aligns with contemporary pedagogical approaches to integrating digital tools into the educational process.

The results from the student survey presented in Table 1 clearly indicate a positive impact of using Sketchfab on their learning outcomes. Specifically, 85% of students reported that the platform helps them better understand the learning material. This underscores the

effectiveness of visualizing complex concepts through 3D models, which is crucial for deepening understanding and knowledge acquisition in demanding academic disciplines. 78% of students noted an increase in motivation to learn, highlighting the significant role of interactive and visual technologies in stimulating interest in the learning process. Moreover, 90% of students recognized improvements in their spatial thinking, which is a key competence for solving problems in technical and natural sciences. Additionally, 72% of students reported that the platform made working on projects easier, supporting the development of critical thinking and creativity during project-based work.

TABLE 1 IMPACT OF USING SKETCHFAB ON LEARNING OUTCOMES
(SURVEY OF STUDENTS)

Learning outcome	% of Students agreeing
Better understanding of the material	85%
Increased motivation	78%
Development of spatial thinking	90%
Facilitation of project work	72%

In conclusion, the analysis of both tables suggests a high level of integration of Sketchfab into the learning process, positively influencing educational outcomes. The increase in platform usage time and the high percentage of positive feedback from students confirm the significance of this technology in developing modern competencies such as spatial thinking, autonomy, creativity, and motivation for learning. Given these results, it is recommended to further integrate Sketchfab into educational programs to foster the development of digital and cognitive skills among students.

The research findings indicate the active utilization of the platform by both educators and students. The average time instructors spend on Sketchfab is 3.5 hours per week, demonstrating its integration into the instructional process, particularly for the visualization and development of 3D models applicable across various subject domains. Conversely, students allocate more time to Sketchfab (5.2 hours per week), reflecting a high level of engagement and intrinsic motivation in their learning activities. This degree of involvement underscores the potential of this technology in fostering cognitive skills, particularly spatial reasoning, imagination, and self-directed learning. The overall average usage (4.3 hours per week) highlights a growing shift toward interactive learning, aligning with contemporary pedagogical frameworks that emphasize the integration of digital tools into the educational environment.

IV. CONCLUSIONS

The analysis of Sketchfab usage in the educational environment demonstrates a steady increase in adoption among both teachers and students, highlighting the growing role of 3D visualization technologies in contemporary pedagogical practices. The observed rise in

the number of users underscores the platform's relevance in facilitating immersive, interactive, and student-centered learning experiences.

The integration of Sketchfab into the instructional process serves multiple pedagogical functions, including enhancing spatial cognition, supporting interdisciplinary project-based learning, and fostering digital literacy. The data reveal that educators primarily utilize the platform for the visualization of complex three-dimensional models, which contributes to cognitive load reduction and improved conceptual understanding, particularly in STEM disciplines. Simultaneously, students engage with Sketchfab not only for academic purposes but also for self-directed learning and creative exploration, reflecting the shift towards constructivist and inquiry-based learning paradigms.

The increase in weekly usage hours among students compared to teachers suggests a higher degree of learner autonomy and motivation in interacting with 3D content. This trend aligns with contemporary educational frameworks emphasizing active learning, digital fluency, and the development of metacognitive skills. Furthermore, survey results indicate that students perceive Sketchfab as a valuable tool for improving learning outcomes, particularly in terms of knowledge retention, problem-solving abilities, and overall academic engagement.

From a methodological perspective, the findings underscore the necessity of structured pedagogical strategies for the successful integration of 3D visualization tools into competency-based education. Effective implementation requires that educators receive specialized training and methodological support to maximize the didactic potential of immersive technologies. Moreover, institutional investment in digital infrastructure and curriculum adaptation is crucial for ensuring the sustainability and scalability of digital learning innovations.

Despite these promising results, the study has several limitations. The research primarily focuses on short-term adoption trends, necessitating further investigation into the long-term cognitive effects of immersive visualization technologies. Additionally, while this study examines user perceptions and engagement patterns, future research should employ experimental and longitudinal designs to assess the direct impact of 3D visualization tools on learning outcomes, skill development, and cognitive load reduction. The generalizability of findings is also limited to the specific context of agroengineering education, warranting further exploration of discipline-specific applications in other STEM fields.

As digital transformation in education accelerates, future research should explore scalability, accessibility, and inclusivity in implementing immersive visualization tools in hybrid and distance learning environments. Investigating best practices for integrating 3D modeling into STEM curricula and examining its role in fostering

critical thinking, collaborative learning, and interdisciplinary approaches would provide valuable insights. Additionally, exploring the potential of AI-driven 3D modeling and augmented reality (AR) integration could further expand the pedagogical applications of immersive learning technologies in agroengineering and related technical disciplines. Future studies should also examine the interaction between immersive visualization tools and adaptive learning technologies, exploring how AI-driven recommendations and personalized learning pathways can enhance student engagement and knowledge retention. Furthermore, comparative research across different educational institutions and geographic regions could provide insights into contextual factors influencing adoption rates and effectiveness.

Another crucial direction for further research involves assessing the cost-effectiveness and return on investment of integrating 3D visualization tools in higher education, particularly in resource-constrained settings. Understanding the institutional and infrastructural challenges associated with large-scale implementation would help policymakers and educational administrators make informed decisions about the sustainability of digital learning initiatives.

Lastly, as digital education continues to evolve, interdisciplinary research collaborations between educators, cognitive scientists, and technology developers could lead to the creation of more interactive, AI-enhanced, and pedagogically optimized 3D learning environments. Investigating the potential of virtual reality (VR) and mixed reality (MR) extensions of Sketchfab could provide a more immersive and experiential approach to agroengineering education, further bridging the gap between theoretical knowledge and hands-on technical skills development.

V. ACKNOWLEDGMENTS

The author expresses sincere gratitude to colleagues and educators who have contributed to the conceptual development of this study by sharing their insights into the integration of immersive technologies in education. Special appreciation is extended to researchers in the field of educational technology whose prior work has provided a solid theoretical foundation for analyzing the pedagogical affordances of Sketchfab in fostering digital literacy, spatial reasoning, and constructivist learning experiences.

Furthermore, we acknowledge the academic community's contributions in developing of interdisciplinary methodologies that enhance student engagement and cognitive development through innovative digital tools. The increasing adoption of 3D visualization platforms in education underscores the relevance of ongoing research in the field, and the author acknowledges the invaluable contributions of those advancing the discourse on interactive and multimodal learning environments.

Deep appreciation is expressed to all educators and students who participated in the study, providing empirical insights into the pedagogical applications of Sketchfab. Their engagement and feedback have been instrumental in shaping the analysis and reinforcing the significance of immersive technologies in contemporary educational paradigms.

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Developing Critical Thinking in Mathematics Lessons for Fourth Graders

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Abstract—This study explores the development of critical thinking skills among fourth-grade students within the Lithuanian curriculum, where students are expected not only to perform calculations but also to formulate hypotheses, justify solutions, and explore alternative problem-solving methods (Mathematics General Curriculum, 2022). Despite curricular ambitions, many teachers lack clear strategies for fostering these skills in practice. To address this, a qualitative study using semi-structured interviews with six primary school mathematics teachers was conducted. The interviews were transcribed and analysed through content analysis to uncover common methods and challenges. Findings revealed that teachers encourage critical thinking through interactive tasks, real-life problem analysis, mathematical storytelling, project work, group discussions, and the use of digital applications. Key activities supporting critical reasoning include problem-solving tasks, mathematical modelling, reflective exercises, and structured classroom discussions. However, the study identified a persistent difficulty among teachers in selecting and designing tasks that effectively stimulate analytical thinking. As a result, the research recommends implementing more structured, student-centered strategies and collaborative learning to better cultivate critical thinking. Furthermore, the integration of inquiry-based learning and digital technologies is emphasized as promising in enhancing students' analytical and problem-solving abilities. The insights gained from this study provide valuable guidance for teachers seeking to align instructional practices with curriculum expectations and promote deeper mathematical reasoning from an early age.

Keywords— *critical thinking, mathematics education, logical reasoning, problem-solving.*

I. INTRODUCTION

Relevance. Critical thinking prepares students to comprehend and apply mathematical concepts. According to OECD [1], critical thinking assists students in decision-making, observation, and applying knowledge to practical situations. Critical thinking in mathematics involves argument identification and construction, using evidence

and reasoning to support or critique claims by assessing the reliability and validity of information sources [2].

The Lithuanian education system intends to form students' cognitive competences, wherein critical thinking is considered one of its constituents. It is assumed by the new mathematics general curriculum [3] that students from the fourth grade will be able to execute mathematical operations, analyse mathematical objects, make hypotheses, argue about the solutions, and even check alternative methods of problem-solving. A study conducted recently emphasized that instructional methods like inquiry-based learning [4] as well as problem-based learning [5] contribute much towards such skill development.

Novelty. What this study found is that critical thinking helps students solve mathematical problems, develop and evaluate mathematical ideas, reason, and explain results. This affects student motivation and achievement positively. However, the factors that influence how critical thinking is acquired and assessed in an educational environment are very complex and under researched. Actual critical thinking mathematics depends much on the approach, method, and task of the teacher. According to the findings from Su et al. [6] and the dynamic approach of critical thinking, it can be enhanced through appropriate pedagogy.

Recent studies indicate that the integration of digital tools, as well as AI applications, may offer effective opportunities for the development of critical thinking as approaches to mathematics education [8]. Nevertheless, many difficulties are experienced in the probability of creating the correct lessons that will consequently improve these skills [7]. Other research has proven that approaches such as STEM-based discovery learning and technology-supported instruction go a long way in enhancing students' analytical thinking and attentiveness.

Research problem. The research problem lies in the fact that the development of critical thinking has become an integral part of modern primary education; however, there

Online ISSN 2256-070X

<https://doi.org/10.17770/etr2025vol3.8563>

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is much room for improvement in how it is integrated into mathematics lessons. In the updated mathematics program expected in 2022, it is expected that a fourth-grade student will be able not only to operate with mathematical procedures, but also to research mathematical objects, form hypotheses, argue the decisions made, and compare alternative strategies [3]. Developing critical thinking includes the following key areas: deep understanding and reasoning, mathematical communication, and problem solving. For the student to understand and reason deeply, it is necessary to introduce him to the study of mathematical objects and properties to hypothesize the place of these objects in the system of some previous objects; the latter process involves inductive reasoning. Mathematical communication will include the ability to analyse and interpret mathematical ideas in a variety of ways and to be able to see the logical connections on which they are based. Problem solving will involve evaluating the results of their actions and making informed decisions about them. However, in practice, very often there is no clear methodological base that allows for the effective development of these abilities, and, most importantly, teachers experience certain difficulties in choosing tasks suitable for stimulating critical thinking. Considering what has been revealed, the research problem can be formulated as follows: how to develop critical thinking of fourth-grade students in mathematics lessons. The research question focuses on the development of critical thinking in fourth-grade mathematics lessons.

The aim of the study is to investigate the process of developing critical thinking of fourth grade students during mathematics lessons and to determine the most effective strategies and methods that promote the formation of those abilities.

Study objectives:

1. To describe the importance and achievement of critical thinking in the mathematics general curriculum.
2. To present methods for the development of critical thinking in mathematics lessons.
3. To investigate how primary school teachers, develop critical thinking in mathematics lessons for fourth grade pupils.

Research methods: Scientific and methodological literature review, semi-structured interviews, and content analysis.

Importance of research. The results will help to understand and support the methods of developing critical thinking in students' mathematics lessons in the fourth grade, the most effective methodological tools and the problems faced by teachers. Thus, teachers can be given recommendations on how best to encourage students' critical thinking through assignments and discussions.

II. MATERIALS AND METHODS

A. Literature review

A1. Critical thinking achievement in mathematics lessons

Mathematics is one of the subjects in which critical thinking skills can be developed and applied. In mathematics lessons, pupils are exposed to a variety of tasks that require them to analyse information, find patterns and relationships, apply mathematical procedures and principles, reason and evaluate their own and others' judgements, and model and interpret situations [3]. The mathematics achievement areas include problem solving, which includes elements of critical thinking. Problem solving in mathematics involves the ability to 'model situations that are comprehensible and meaningful in different contexts: decompose a problem into its parts, determine the relationship between them, formulate a mathematical question/task; propose and evaluate alternative strategies for solving a problem, make a plan for solving the problem, and implement the plan; evaluate the results of mathematical activities, draw conclusions, and interpret them in the context of the problem under consideration' [3, p. 17].

The mathematics outcomes that require critical thinking include performing and reasoning mathematical procedures, investigating mathematical objects and formulating hypotheses, making and proving the logicity of a sequence of statements or a solution to a problem, analysing and interpreting the logical relationships between the elements of a mathematical message, proposing and evaluating alternative strategies for solving the problem, designing and implementing a plan for solving the problem, evaluating the results of the mathematical activity and drawing conclusions (see Table 1).

TABLE 1 MATHEMATICS ACHIEVEMENT IN CRITICAL THINKING

Achievement area	Mathematics achievement
Deep understanding and reasoning	Explores mathematical objects, formulates hypotheses about their general properties and their place in a system of previously studied objects (Inductive reasoning).
	Develops a coherent, logically sound sequence of statements or solution to a problem, evaluates the logicity of the reasoning, and proves mathematical statements (Deductive Reasoning).
Mathematical Communication	Analyses and interprets the logical relationships between the elements of a mathematical message presented in different forms (text, figure, diagram, formula, table, drawing, graph, chart).
Problem solving	Evaluates the results of mathematical activities, draws valid conclusions and interprets them.

Compiled according to Framework for Mathematics, 2022

A2. Deep understanding and reasoning

The ability to investigate mathematical objects and to formulate conjectures is a core aspect of mathematical thinking. The Framework for Mathematics (2022) states that pupils should be able to provide a coherent argument for their statements and judgments, justifying them with both inductive and deductive reasoning [3]. According to Maulana et al. [14], students can understand structure and pattern better through the practice of making and testing conjectures. This fact is also underlined by Nugraheni et al. [15], who argue that mastery of reasoning, particularly the core concept behind it, will greatly support students in applying their knowledge of mathematics to many problems. Thus, it should be taught explicitly at school. Nevertheless, many students face challenges in assessing the logical validity of statements, and therefore the development of mathematical reasoning needs to be actively encouraged.

A3. Mathematical communication

The ability to express mathematical reasoning accurately in different forms is important for the development of logical reasoning. The Mathematics General Curriculum (2022) specifies that pupils should be able to interpret mathematical statements presented in text, diagrams, tables, or other visual methods [3]. Results found in a study conducted by Jannah et al. [9] show that a well-explained presentation of mathematical content aids students in knowledge assimilation and makes them more adept at analysing the data given. Tashtoush et al. [8] noted that interactive discussions help students understand the details of problem-solving techniques and how they can be used to assess different arguments. However, not all students are easily able to express their mathematical reasoning accurately, so active communication skills training is needed.

A4. Solving problem

The process of mathematical problem-solving entails the formulation, assessment, and implementation of a plan of solution. The Framework for Mathematics (2022) insists on the need for the pupils to critically appraise the results from mathematical activities, draw valid conclusions, and make an interpretation of the results. Harahap et al. [7] observe that students who learn to analyse and compare different problem-solving strategies have a better understanding of the structure of mathematical reasoning. Active involvement in the process of solving the problem, as argued by Sukardi et al., [16] will help the students visualize and decide for themselves the appropriateness of strategies in reaching a solution. However, challenges remain in terms of students' ability to systematically apply critical thinking techniques in real mathematical situations.

Critical thinking skills developed in mathematics classes are the most important teaching process that allows students not only to understand mathematical concepts but also to apply them to solve real-world problems. Mathematical reasoning, communication, and problem-solving are higher-order thinking skills that allow students to flexibly apply knowledge in a variety of contexts [10], [11]. However, there are certain problems with the

application of critical thinking skills, so there is a need to further improve teaching methods, as well as methods that promote the assimilation of theoretical knowledge through their critical analysis and reflection.

A5. Methods for Developing the Critical Thinking

The development of critical thinking abilities in mathematical lessons plays an intrinsic part in facilitating students not only in acquiring knowledge but also in applying, analysing, and even justifying the same. The Mathematics Curriculum (2022) states that students can explore mathematical objects, hypothesize, and evaluate alternative solution strategies [3]. According to Zhou et al. [4], mathematics instruction supported by critical thinking presents students with an opportunity to explore various approaches to solving problems; this will help to enhance their logical reasoning and the use of mathematics in different real-world situations. This view is also supported by a study by Maryani et al. [5], which suggests that students who participate actively in analytical activities generally have better abilities to apply different arguments for the application of motivation and involvement in learning. This view is very different from the view of traditional teaching since it very often makes use of the passive critical thinking of the learners; hence, it is not applicable to this context of instructional innovation.

A6. Methods Based on Problem-Solving

One of the best ways to enhance critical thinking in mathematics classes is to apply problem-based teaching and learning. Sukardi et al. [16] stated that this method encourages students not only to search for solutions but also to check their validity, look for alternative approaches, and analyse the logic of solutions. The views of Harahap et al. [7] support the idea that working with problem-solving activities enables students to apply theoretical mathematical knowledge to real-life situations, thus improving their practical problem-solving skills. This approach fosters self-reliance and builds confidence, as pointed out by Maulana et al. [14]. But this way needs strong teacher help to aid students not just get but also build the problem-solving process, mainly for those who miss analytical thinking.

A7. Methods of Mathematical Argument and Discussion

The talk should be a big part that helps well to show students prove their math thoughts and choices with smart arguments. According to Jannah et al. [9], mathematical discussions are highly beneficial, giving students the opportunity not only to express their opinions but also to learn to listen to others, evaluate their arguments, and compare different points of view. The same collaboration supports the students' critical thinking techniques in communicating their thoughts—a factor directly related to academic achievement and successful problem resolution, as emphasized by Tashtoush et al. [8]. This finding is supported by Er [17] in that discussion and argumentation cultivates the capability of students to logically structure their ideas and, therefore, the audience can be answered

with solutions that are more precise and with sound conclusions. Some students are not willing to participate in the discussion because of knowledge; therefore, it should be an environment where learning can be very supportive, not about getting the right answer but about developing a thought process to get the right answer.

A8. Methods for Mathematical Modelling and Reflection

Contemporary approach that allows learners to understand rules in mathematics and apply them in real-life situations. As described by Jamil et al. [18] it gives the students a chance to experiment with different methods of problem-solving, compare different approaches, and explain the results obtained. This view is also supported by Yu et al. [19] who argue that reflective practice, for example learning journals for students or self-evaluation tasks that will enable students to critically assess their learning in developing how their reasoning has emerged with time. Therefore, Nugraheni et al. [15] argue that such students become more independent and aware of their own progress. However, this assumption does not always hold in real conditions. Sometimes, students are not naturally inclined to reflect on their learning; thus, it becomes the responsibility of the teacher to systematically incorporate reflective questions into daily teaching.

Improving critical thinking during mathematics courses helps raise the academic performance of students due to better-informed decision-making capabilities and proper application of mathematical knowledge to real-life situations. Among the effective approaches are problem-solving-based instruction, discussion and argumentation strategies, mathematical modelling, and reflection. Best practices support this claim [10], [11]. The effectiveness of these methods depends on the delivery mechanism of the content by instructors and the student's level of involvement in the learning process. Critical thinking tasks should cease to be separate extra tasks and should be an integral part of the teaching of mathematics so that students will not only memorize formulas but also learn to analyse, evaluate, and justify decisions.

B. Methodology of the research

B1. Research Instrument

A qualitative research approach was applied, allowing the researcher to pose pre-prepared questions while also giving participants the freedom to express their thoughts. This approach facilitates the discovery of new, unexpected aspects of the research topic [13].

A semi-structured interview was chosen as the primary data collection method, enabling a deeper understanding of the critical thinking development methods used by primary school teachers in mathematics lessons. In the semi-structured interviews, the researcher used open-ended questions determined prior to studying the reviewed literature. The study was intended to find out how the teachers included techniques in their lesson plans to develop critical thinking in mathematics and the type of tasks selected to encourage students to think critically. It

also seeks to determine how teachers assess the effectiveness of these methods. Additionally, the semi-structured interview format allowed the researchers to capture teachers' opinions on the importance of critical thinking development and the challenges they face in implementing these methods in their lessons [12], [11].

B2. Research Sample

The study included six primary school teachers selected based on their professional experience and participation in training programs related to the implementation of the updated mathematics curriculum. The participants' ages ranged from 25 to 35 years, with teaching experience varying between 2.5 and 10 years. All participants were women working in primary schools (see Table 2).

TABLE 2 CHARACTERISTICS OF RESEARCH PARTICIPANTS

Participant Code	Age	Teaching Experience (Years)
M1	25	2,5
M2	27	6
M3	34	10
M4	26	5
M5	28	7
M6	35	11

B3. Research Process

Interviews with primary school teachers were conducted between February and March 2024. All informants were professional acquaintances of the researcher. The interviews were scheduled in advance, and the questions were not disclosed to the informants beforehand. Four interviews were conducted remotely via the ZOOM platform, recorded both on ZOOM and using a voice recorder, while two interviews were conducted in person at the workplace of one of the researchers and recorded using a voice recorder.

Before each interview, participants were informed about the study and consented to the recording. The duration of the interviews varied: 22, 33, 35, 40, 45, and 46 minutes. Over time, interviews became longer as the researcher refined the questions based on transcriptions from previous interviews to ensure the research objectives were met. Initially, the sample size was set at five participants; however, one additional participant was included to achieve data saturation (Jannah et al., 2025). Participants were encouraged to provide detailed responses, and follow-up questions were used to clarify their perspectives.

After all interviews were conducted, the recorded data was transcribed verbatim, separating participants' responses from the researchers' questions, with the latter highlighted to facilitate distinction. Data analysis was performed using content analysis, identifying meaningful units—categories and subcategories—from the collected responses. The data were first grouped into subcategories using an inductive approach and then categorized

accordingly. The research findings are illustrated with direct participant quotes.

B4. Ensuring Ethical Research Principles

The study adhered to ethical principles of voluntary participation, privacy, and confidentiality [13]. Participation was entirely voluntary, and respondents had the freedom to decide which questions they wished to answer and to choose the interview format and location that suited them best. Participants were informed about the research purpose, and their consent was obtained before recording the interviews. Confidentiality was ensured, and personal data was not disclosed. The interview questions did not contain any information that could compromise participant privacy. The researchers ensured full confidentiality of the interviews, assigning participant codes during transcription. The demographic data of participants was presented in a fully anonymized format [16].

III. RESULTS AND DISCUSSION

C. Encouraging students to explore mathematical objects and formulate hypotheses

The first question aimed to find out how primary school teachers encourage pupils to explore mathematical objects, to formulate hypotheses about their general properties and their place in the system of previously studied objects. Teachers' responses reveal the variety of teaching methods used, which can be grouped into several main categories: interactive tasks, virtual mathematics programmes, analysis of real-life problems, mathematical tales and stories, project work, mathematics laboratories (see Table 3).

TABLE 3 TEACHERS' METHODS FOR ENCOURAGING STUDENTS TO EXPLORE MATHEMATICAL OBJECTS AND TO FORMULATE HYPOTHESES ABOUT THEIR GENERAL PROPERTIES AND THEIR PLACE IN A SYSTEM OF PREVIOUSLY STUDIED OBJECTS (INDUCTIVE REASONING)

Category	Subcategory
Interactive tasks	Geometric constructors
	Group discussions
	Hypothesis generation
Virtual maths apps	Experimenting with objects
	Formulating hypotheses
	Testing
Analysis of real-life problems	Geometric planning
	Putting hypotheses into practice
Mathematical tales and stories	Search for hidden objects
	Discussion of links to known objects
Project work	Setting object properties
	Comparing hypotheses with theory
	Delving deeper into the world of maths
Mathematics laboratories	Manipulators for object perception
	Developing hypotheses based on observations

Teachers' responses to the question of how they encourage students to explore mathematical objects and formulate conjectures reveal their teaching methods using

interactive tasks and virtual mathematics software: "I encourage students to explore mathematical objects using interactive tasks <...>" (M1) emphasising the use of interactive tasks, allowing students to use geometric constructors to understand the properties of shapes and encouraging them to develop their own hypotheses and to discuss in groups, "In my lessons, fourth grade students work with virtual mathematics applications <...>" (M2) highlighting the benefits of virtual mathematics applications by giving students the opportunity to experiment and to formulate hypotheses based on the results obtained. Teachers use methods related to the analysis of real-life problems, mathematical stories and tales, project work and the mathematics laboratory: "I present real-life problems to students <...>" (M2) by having students analyse mathematical objects in a practical way, for example by planning a soda, "I use mathematical stories and tales <...>" (M4) using mathematical fairy tales and stories as a tool for exploration, encouraging pupils to look for hidden mathematical objects and properties, "I give pupils the opportunity to work in projects and mathematics laboratories <...>" (M5) and (M6) give examples of projects and mathematics laboratories where pupils go deeper into the investigation of mathematical objects and the formulation of conjectures. The findings align with the work of other researchers who highlight the importance of active learning, exploration, and problem-solving in developing students' mathematical reasoning [10], [12].

D. Encouraging pupils to construct a coherent, logical sequence of statements or a solution to a problem, to evaluate the logic of reasoning, to prove mathematical statements

The second question aimed to find out how primary school teachers encourage pupils to construct a coherent, logical sequence of statements or solutions to a problem, to evaluate the logic of their reasoning, and to prove mathematical statements. Teachers' responses reveal a variety of teaching methods used, which can be grouped into several main categories: problem-solving activities, proof of mathematical statements, classroom discussions, group activities, mathematical diaries, and mathematics laboratories (see Table 4).

TABLE 4 TEACHERS' METHODS FOR ENCOURAGING STUDENTS TO CONSTRUCT A COHERENT, LOGICAL SEQUENCE OF PROPOSITIONS OR A SOLUTION TO A PROBLEM, TO EVALUATE THE LOGIC OF REASONING, TO PROVE MATHEMATICAL STATEMENTS (DEDUCTIVE REASONING)

Category	Subcategory
Problem-solving tasks	Application to real-life situations
	Critical and logical thinking
Proofs of mathematical statements	Making calculations
	Logical explanation of decisions
Classroom discussions	Communication and sharing of arguments
	Critical evaluation and requirement for logical explanations

Group activities	Constructing and defending arguments
	Developing structured and logical arguments
Mathematical diaries	Capturing thinking progress
	Improving logic skills
Mathematics laboratories	Experimenting with methods
	Practical application and finding the most logical solutions

Teachers use a variety of methods to promote the ability of Year 4 pupils to construct coherent and logical sequences of statements: 'To encourage pupils to construct coherent and logical sequences of statements, I use problem-solving activities <...>' (M1) emphasising problem-solving activities that require the application of mathematical concepts to real-life situations, 'In my lessons I emphasise the importance of proofs of mathematical statements <...>' (M2) emphasising the importance of proving mathematical statements by asking students not only to perform calculations but also to explain their correctness, 'I use classroom discussions to allow students to share and evaluate each other's arguments <...>' (M3) using classroom discussions to allow students to share and evaluate each other's arguments, helping them to understand the specificity of logical argumentation, 'In order to promote logical thinking, I organise activities <...>' (M4) by organising group activities in which pupils construct and defend arguments to develop structured and logical thinking, 'I encourage pupils to write mathematical diaries <...>' (M5) by encouraging pupils to write mathematical diaries that allow them to record their thinking and develop their logical skills, 'In my classes, I often use 'maths labs' <...>' (M6), emphasising the use of maths labs where students experiment and search for proofs by applying mathematics in practice. These methods show that teachers value critical thinking, logical reasoning and the practical application of mathematics as important skills to be developed at school. The findings align with the work of other researchers who highlight the importance of problem-solving, discussion, group work, and reasoning in developing students' critical thinking and mathematical understanding [10], [12], [14].

E. Encouraging students to analyse and interpret a mathematical message

The third question aimed to find out how primary school teachers encourage pupils to analyse and interpret the logical relationships between the elements of a mathematical message presented in different forms (text, picture, diagram, formula, table, drawing, graph, chart). Teachers' responses reveal the variety of teaching methods used, which can be grouped into several main categories: text analysis and interpretation, mathematical concepts, visual aids, mathematical shapes and formulae, group activities, data collection and analysis, and the integration of different forms (see Table 5).

TABLE 5 TEACHERS' METHODS FOR ENCOURAGING STUDENTS TO ANALYSE AND INTERPRET A MATHEMATICAL MESSAGE

Category	Subcategory
Text analysis and interpretation	Text tasks: students analyse and explain mathematical relationships using text examples
Mathematical concepts	A description of how the area of a figure changes with the length of its sides.
Visual aids	Tables and graphs: used to explain and represent mathematical relationships
	Drawings and diagrams: help you understand and interpret functions and their properties
Mathematical forms and formulae	Diagrams: pupils learn to recognise relationships between mathematical elements
	Formulas: used to explain mathematical models such as geometric progression
Group activities	Group discussion: students analyse and interpret mathematical data presented in different forms
	Presentations: students share their findings with the class
Data collection and analysis	Collecting data: students create tables and graphs based on the data they collect
	Interpreting data: students learn to understand the importance of data analysis
Integration in its various forms	Text, drawings, formulae: Pupils use different forms to analyse mathematical relationships
	Comparison: students compare the areas of different shapes using visual and mathematical expressions

The study reveals a variety of teaching methods used by primary school teachers to encourage fourth-graders to analyse and interpret a mathematical message: for example, <...To promote fourth-graders' analysis and interpretation skills, I use text tasks in which students have to find and explain mathematical relationships...> (M1) assessing the students' ability to not only perform calculations, but to express themselves clearly in writing, which is an important aspect of critical thinking, <...In my lessons, students often work with diagrams and formulas...> (M2), suggesting that the teacher encourages students to see mathematics as a system in which each element is related to the next...<...I encourage students to use drawings and diagrams to understand mathematical relationships...> (M3) in order to teach them how to visually represent and analyse information, which is especially useful for problem-solving and data analysis, <...Interpretive skills are developed through group discussions...> (M4) emphasising that group activities encourage students to share ideas and deepen their understanding of mathematical concepts, <...I encourage my students to create their own tables and graphs...> (M5) valuing students' ability not only to follow instructions but also to use mathematics creatively in their work, <...In my lessons, my students learn to analyse mathematical relationships using different forms...> (M6) emphasising the importance of analysis by encouraging students to look for connections between different aspects of mathematics and to apply them in practice. Both teachers emphasise the importance of practical work with data, encouraging students not only to learn theory but also to apply their knowledge in real situations, which is essential for understanding the meaning and importance of

mathematics. The results of the study align with the work of other researchers who emphasize the importance of text tasks, diagrams, formulae, drawings, group discussions, and working with data in developing students' abilities to analyse and interpret mathematical messages [9], [10], [12].

F. Encouraging pupils to evaluate the results of mathematical activities, to draw valid conclusions and to interpret them

The fourth question asked how primary school teachers encourage pupils to evaluate their mathematical performance, draw valid conclusions and interpret them. Teachers' responses reveal a variety of teaching methods used, which can be grouped into several main categories: individual choice and independence, group work and collaboration, process relevance and exposing thinking, self-testing methods, and the use of technology and interactive tools (see Table 6).

TABLE 6 TEACHERS' METHODS FOR ENCOURAGING PUPILS TO EVALUATE MATHEMATICAL PERFORMANCE, MAKE VALID INFERENCES AND INTERPRET THEM

Category	Subcategory
Individual choice and autonomy	Allowing students to choose tasks according to their personal abilities
	Encouraging self-assessment of work done
Working in groups and collaboration	Using group work to complete tasks and present results
	Learning from your own and others' mistakes and achievements
The importance of process and uncovering thinking	Emphasising not only the importance of the right answer but also the process by which it was arrived at
	Promoting the ability to explain thinking processes and problem solving
Self-testing methods	Use of various self-testing methods such as checklists or reflective diaries
	Critical thinking and error analysis
	Encouraging critical thinking by analysing mistakes and finding their causes
	Use of interactive learning tools that allow students to see their progress in real time

The study reveals a variety of teaching methods used by primary school teachers to encourage pupils to evaluate their mathematical performance, draw reasonable inferences and interpret them. The teacher stresses the importance of students' choice, allowing them to choose tasks that are appropriate to their abilities and then discussing their decisions: "I encourage students to evaluate their mathematical performance by letting them choose the tasks according to their abilities. Afterwards, we discuss together how it went and what could be done differently." (M1). Such lessons require that the students are made to work in groups, where they must execute tasks and present the outcomes to others as well. This will enable them not just to draw conclusions but also learn from their errors and through the achievements of their friends. (M2) which encourages students not only to complete the tasks but also to share the results and learn from their mistakes and their friends' successes. The

teacher also identifies the importance of process thinking: "I always emphasise the importance not only of the right answer, but also of the process by which it was arrived at. Students need to be able to explain their thinking process and how they solved problems." (M3) encouraging pupils to analyse and explain their thinking process. The teacher suggests self-assessment methods as a way of: "I encourage pupils to self-assess their work using a variety of self-assessment methods such as checklists or reflective diaries." (M4) for students to assess their own progress. The teacher emphasises the importance of critical thinking: "I think it is important to teach students not only mathematics but also critical thinking. That is why I encourage them to analyse mistakes and look for reasons why something didn't work as it should have...>" (M5) not only to complete the tasks but also understand the process of doing them. The benefits of technology are also noted by this teacher "I use various interactive technologies, such as learning apps, which allow students to see their progress in real time and encourage them to improve...>" by actively involving students in the learning process and showing them their own achievements. These teachers' approaches denote multi-facetedness in teaching, calling for reflection not just on one's math performance but on critical thinking, self-efficacy, and collaborative skills.

IV. CONCLUSIONS

The acquisition of critical thinking involves justifying one's knowledge and literacy in mathematics, as well as being a problem solver. All these will enable the students to apply mathematics not only in performing mathematical procedures but in analysing and interpreting information from various forms and applying it successfully outside the classroom.

Discussions, projects, teamwork, and problem-solving activities fit very well into mathematics lessons because they help not only deepen knowledge but also give the ability to explore and discuss. These methods, combined with modelling and feedback, create an active learning environment that motivates students and helps them to make meaningful connections between new and existing knowledge.

To develop critical thinking in mathematics lessons, a variety of methods must be used to promote active participation and deep understanding of mathematics among fourth-grade pupils: Group discussions, interactive tasks, project work and mathematical diaries help pupils to formulate hypotheses, argue their ideas, solve problems and reflect on their learning process. A variety of tasks that encourage deductive reasoning and the search for creative solutions develop students' analytical and problem-solving skills. The use of such learning tools, texts, visual aids and most importantly allows the students to effectively analyse and interpret information of a mathematical nature. Due to the above it is also important to better understand the significance of collaboration and teamwork which will consequently help them learn through each other and improve their communication skills. The teacher should give challenges that include but are not limited to fear of

making mistakes, habitual dependence on direct instruction, and scarcity of resources when designing problem-solving activities for the students at the fourth-grade level. The development and improvement of the methods of work based on individual characteristics of students are required for effective mastering of the skills of critical analysis.

V. RECOMMENDATIONS

- The primary school teachers should use the following methods to develop critical thinking among their students in mathematics lessons:
- Problem solving and proving mathematical statements or engaging in discussions and group activities would promote students to develop deductive reasoning.
- It will give students an opportunity to reflect and deepen their knowledge of mathematics through mathematical journals and laboratory work.
- Different forms of presentation can be integrated to allow students to analyse and interpret a mathematical message.
- This will discuss and bring out the fact that group discussion and collaboration bring out deeper understanding and, on top of that, gives the students a chance to argue their ideas
- Interactive tasks, virtual applications, mathematical tales and project work encourage critical thinking, group discussion and conjecture.
- Discussions, projects, authentic and problem-solving tasks, and group work help students to deepen their mathematical knowledge and logical thinking, and allow them to explore, question and discuss.
- Simulation and feedback provide an active learning environment that allows students to effectively link prior knowledge with new knowledge.
- Creativity skills and teamwork encourage pupils to propose and evaluate alternative strategies for solving a mathematical problem
- Interactive activities, autonomy and reflection help students not only to find solutions but also to make sense of them, to learn from others and to improve collaboration skills
- Group work and collaboration allow learning from peers and improving communication skills.
- The use of technology helps students to see their progress and allows them to visualise mathematical processes.

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Artificial intelligence as an effective tool for personalized learning in modern education

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Abstract- Artificial Intelligence (AI) plays a pivotal role in the modernization of the educational process, particularly in higher education institutions, by enhancing the quality of professional training for future specialists. The integration of AI fosters personalized learning through adaptive technologies that optimize students' educational trajectories based on their individual needs and knowledge levels. This paper explores critical elements such as the implementation of virtual simulations and laboratories, automated assessment systems, and AI-powered learning tools. These innovations contribute to creating a more efficient, interactive, and engaging educational environment. The primary objective of this study is to substantiate the role of AI in personalized learning and improving the efficiency of the educational process. It also aims to analyze the specific features of AI integration into vocational education and assess the impact of adaptive learning technologies, automated assessment systems, and virtual simulations on the training of future professionals. The research employs both theoretical and empirical methods. The empirical research involved an experimental study with the participation of 45 educators and 120 students. To assess the effectiveness of AI integration in educational settings and professional activities, a customized survey was developed. The questionnaire addressed issues such as familiarity with, application of, and perceived benefits from AI-driven tools, including chatbots, automated grading systems, and adaptive learning platforms. The analysis of survey responses reveals widespread adoption of AI technologies among students. Approximately 70% of the students are familiar with these technologies and actively use AI-powered chatbots,

automated assessment systems, and adaptive learning platforms. Virtual simulations and AI-driven learning assistants also contribute to practical skill development, although their full potential remains underutilized due to infrastructure limitations. Among educators, AI adoption is comparatively lower. Only 40% actively use AI in their teaching practices, while 35% apply it on an occasional basis. The main barriers to AI adoption include insufficient technical training (60%), lack of funding (50%), and legal and ethical concerns (40%). Nevertheless, 55% of educators recognize the potential of AI to enhance personalized learning and are willing to integrate AI tools into their teaching methodologies. The study confirms AI's significant potential in improving the educational process. AI-driven adaptive learning environments can accommodate individual learning styles, knowledge levels, and personal preferences. AI-powered assessment tools, such as Google Forms with AI modules, enable efficient and objective evaluation of student knowledge, thereby reducing educators' workload and providing immediate feedback. Virtual assistants, including GPT-based platforms, offer real-time support for learning and task completion, particularly in remote and blended learning environments. The integration of AI in education enhances teaching efficiency, fosters innovative learning methodologies, and prepares students for the evolving demands of the modern job market. The adoption of advanced AI technologies is crucial for developing a competitive educational ecosystem capable of addressing the global challenges of digital transformation. Future research should focus on improving AI accessibility, enhancing educator training, and addressing ethical concerns to fully

Online ISSN 2256-070X

<https://doi.org/10.17770/etr2025vol3.8534>

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harness the benefits of AI in education. Furthermore, the continued development of adaptive algorithms, virtual tutors, and augmented reality will be essential in shaping the future of AI-powered learning environments.

Keywords- *Artificial Intelligence, Automated Assessment, Digital Education, Professional Education.*

I. INTRODUCTION

Modern society is undergoing significant transformations under the influence of emerging technologies, particularly AI, which has become a crucial factor in various fields, including professional education.

The advancement of communication technologies necessitates a reevaluation of physical structures and spaces where individuals live, learn, and work. Physical presence is no longer a prerequisite, making it essential to explore alternative forms of information dissemination. This shift facilitates database management, real-time interaction, and enhanced mobility while improving access to valuable resources [1].

AI is rapidly reshaping the professional landscape and imposing new skill requirements on the workforce, especially in the context of technological advancements [2].

The relevance of the topic lies in the fact that modern education requires innovative approaches that ensure a personalized learning experience and enhance its effectiveness. The use of artificial intelligence opens new opportunities for adapting the educational process to the individual needs of students, fostering interactivity and motivation for learning. At the same time, the implementation of such technologies is accompanied by certain challenges, including ethical concerns, data privacy protection, and the need for educators to be trained in using new digital tools. Therefore, studying the impact of artificial intelligence on personalized learning is crucial for the development of contemporary educational systems.

The readiness of future professionals to engage with digital technologies in their careers depends on their level of digital competence [3].

Among the key skills necessary for successful AI integration in the workplace are analytical thinking and innovation. The ability to process vast amounts of data efficiently and generate novel ideas is becoming a fundamental requirement for professionals. Additionally, active learning – continuous knowledge acquisition and adaptation to technological advancements – is crucial, as the rapid evolution of technology demands lifelong learning. Moreover, complex problem-solving and critical thinking are essential for evaluating AI-generated outputs and making informed decisions. Working with new technologies also requires creativity, originality, and initiative to develop innovative solutions and approaches.

A particular focus should be placed on developing soft skills, such as leadership, social influence, and adaptability. As AI-driven technologies become more prevalent, leaders

must manage teams working with new tools and drive organizational changes. Equally important is the ability to quickly adapt to shifting conditions and transformations introduced by AI [2].

The impact of AI highlights the need for versatility. In an unpredictable world, the most effective safeguard is the ability to evolve across four dimensions – knowledge, skills, character, and learning – and four driving forces – motivation, identity, free will, and purpose. Education is not obsolete, but it requires comprehensive adaptation. AI cannot function autonomously; therefore, it is necessary to develop an integrated framework encompassing declarative (core content), procedural (design-based), conceptual (fundamental principles), and epistemological (meta-level) knowledge. Traditional disciplines must be modernized accordingly. Moreover, attention should be given to contemporary fields such as technology, engineering, social sciences, and entrepreneurship while promoting interdisciplinarity and cross-cutting themes [4].

Despite the numerous benefits of AI adoption, it is important to recognize the potential negative consequences of technological shifts in the labor market, including the displacement of traditional professions. This reality necessitates continuous workforce adaptation and calls for reforms in education and professional training systems [2].

Substantial ethical, technical, and pedagogical challenges lie ahead, and there is a genuine risk that rapid AI advancements in products and services may outpace the education system's ability to understand, manage, and integrate them effectively [5].

Thus, preparing for future professional challenges associated with AI development is a vital component of training a competitive workforce for the modern labor market. This preparation should focus not only on technical skills but also on soft skills, enabling individuals to work efficiently with emerging technologies and adapt to an ever-changing environment.

The integration of AI in education presents new opportunities for enhancing educational quality, improving learning efficiency, and personalizing curricula to meet individual student needs. In professional education, where both theoretical knowledge and practical skills are essential, AI facilitates an interactive, flexible, and personalized learning experience. AI-powered technologies enable the creation of virtual simulations, intelligent tutoring systems, automated assessment tools, and adaptive learning platforms that cater to individual student proficiency levels. However, the use of AI in professional education introduces new societal challenges. These include institutional technological readiness, the development of educators' competencies, and the ethical considerations surrounding AI integration in education. The growing significance of this topic is driven by the rapid expansion of digital technologies and the necessity of preparing skilled professionals for high-tech environments.

Research on AI's role and potential in professional education will help identify the most effective implementation strategies and contribute to enhancing educational practices.

Scientific publications, monographs, articles, and reports focusing on the opportunities, benefits, and drawbacks of AI in education have been analyzed. Androshchuk & Malyuha [6] emphasize that AI can significantly improve the quality of educational services by automating processes and adapting learning to individual student needs. However, achieving these goals requires governmental support and infrastructure development. Panukhnyk [7] examines the role of artificial intelligence in shaping the modern educational environment, highlighting the importance of responsible technology use in education and research. Zatserkivna & Khalimanenko [8] explore AI's role as a tool for educational modernization, emphasizing its impact on pedagogical approaches. The authors justify the necessity of AI integration into learning processes to enhance their efficiency and competitiveness. Gurevych et al. [9] discuss the complexity and multidimensional nature of AI integration in education, addressing both challenges and opportunities. The authors provide a detailed overview of the current situation and propose concrete steps for the effective implementation of AI in the education system. Topuzov & Alekseeva examine the role of innovative technologies, including AI, in ensuring the continuity of education during crisis situations. They propose new approaches to organizing the educational process that meet contemporary challenges [10]. Kovalchuck & Vorotnikova highlight the value of digital methods for teacher professional development, particularly the significance of e-coaching and e-mentoring in modern education, and suggest promising directions for further research [11]. Koval, Oliinyk, Kryvosheia & Khyliia investigate gamification in education and explore the differences between gamification and the use of games in learning processes [12].

Kolomiets & Kushnir [13] discuss the key challenges of using AI in education, particularly issues related to data privacy, financial costs, unequal access, and the risks of technology misuse. They also analyze the impact of AI on scientific research, emphasizing ethical aspects, academic integrity, and providing recommendations for the effective use of technologies in the educational process.

The study by Nazar [14] examines the contemporary influence of AI on education, its advantages in the learning process, the level of awareness in Ukraine, and the prospects for further technological development to improve educational approaches.

Hrytsenchuk [15] analyzed the use of artificial intelligence systems in the digitalization of education, exploring both international and domestic experiences, theoretical and practical aspects of their application, as well as the effects and prospects of using modern AI

technologies, particularly generative AI, to support the learning process, taking into account the regulatory framework and existing challenges.

This study analyzes specific examples of AI applications in education.

Given the existing challenges and issues, this study outlines key directions for the advancement of professional education. Specific measures have been proposed to address urgent concerns and facilitate the reorientation of vocational training programs to improve their quality. These include participation in EU-funded projects, the development of specialized training modules and courses to support continuous professional development for educators, the enhancement of curricula to improve the technical infrastructure of vocational education institutions, and the upskilling of teaching staff [16].

II. MATERIALS AND METHODS

The purpose of this study is to substantiate the role of AI in personalized learning and enhancing the effectiveness of the educational process, analyze the features of its integration into vocational education, and assess the impact of adaptive learning technologies, automated assessment systems, and virtual simulations on the training of future specialists.

The research methodology combines theoretical analysis, experimental research, and data collection through surveys.

To examine the development of AI in education, a detailed review of international and domestic scientific publications, monographs, articles, and studies related to personalized learning through AI technologies was conducted. Special attention was given to modern approaches to using intelligent systems in educational processes, which enable the adaptation of learning materials to the individual needs of students. A comparative analysis of the application of AI tools such as chatbots, intelligent tutors, adaptive learning systems, and other personalization tools was carried out to assess their impact on the learning process. The evaluation was based on student learning outcomes, feedback effectiveness, and student engagement in the process.

To investigate the relevance and practical significance of AI implementation in personalized learning, an experimental study was conducted involving 45 educators and 120 students from Dmytro Motornyi Tavria State Agrotechnological University, Separate Structural Subdivision «Hlukhiv Agrotechnical Professional College of Sumy National Agrarian University» I. Horbachevsky Ternopil National Medical University, and Kryvyi Rih State Pedagogical University. A survey was developed for data collection.

The student survey focuses on studying the use of AI technologies in learning. It assesses students' familiarity with AI, the frequency of using tools such as chatbots and

adaptive platforms, and their effectiveness in personalized learning. The survey also explores students' attitudes towards the potential of AI replacing teachers and the challenges they face when using these technologies.

The educator survey focuses on the application of AI in teaching. It investigates which AI tools educators use, how they evaluate their impact on personalized learning, and their effectiveness in teaching. Additionally, it identifies the challenges associated with AI implementation, such as technical or financial barriers, and explores the readiness of educators for training and development in this area.

Quantitative data from the surveys and experimental assessments were processed using descriptive statistical methods. Qualitative responses were analyzed thematically to identify key ideas related to the effectiveness and limitations of AI in education.

The combination of theoretical research, empirical experiments, and survey analysis provides a comprehensive understanding of the role of artificial intelligence in modern education.

III. RESULTS AND DISCUSSION

According to the findings of the "Future of Jobs" survey, the most significant transformative trend in the coming years will be the expansion of digital access, which is expected to substantially alter both technological processes and business operations. It is projected that by 2030, 60% of employers will consider this phenomenon critical for the development of their companies. Technological advancements, particularly in artificial intelligence (AI) and data processing (86%), robotics and automation (58%), as well as in energy production, storage, and distribution (41%), are expected to be key drivers of future change. These technologies will influence the structure of workplaces, contributing to the growth of certain occupations while reducing others, thereby increasing the demand for specialists in emerging technologies. Among the most in-demand skills will be expertise in AI, big data, networks, cybersecurity, and technological literacy. Specifically, the demand for big data analysts, fintech engineers, software developers, and machine learning specialists is expected to rise. The most dynamically developing skills include artificial intelligence, big data, networks, cybersecurity, and technological literacy. Additionally, throughout the period from 2025 to 2030, essential personal qualities such as creative thinking, resilience, flexibility, and agility, as well as the ability for continuous learning and development, will remain crucial. Conversely, there is a notable decline in the demand for skills related to physical endurance, manual dexterity, and precision, with 24% of respondents predicting a reduction in the importance of these skills in the coming years [17].

Artificial intelligence is emerging as a key factor in the transformation of workplaces, altering skill requirements for employees. Education plays a vital role in preparing specialists for the changes brought about by AI

development. As demand for new technological skills – such as artificial intelligence, big data, cybersecurity, and programming – continues to grow, education systems must adapt their curricula to equip students for these transformations. This involves not only studying the technical aspects of AI but also fostering soft skills such as critical thinking, creativity, and the ability for lifelong learning. Educational institutions must ensure the flexibility of their programs so that students can effectively adapt to the rapidly evolving technological environment and be prepared for the challenges of the future labor market. The application of AI in education is gaining increasing attention as it has the potential to transform traditional learning approaches. AI can facilitate personalized learning methods, automate assessment processes, and enhance overall educational efficiency. Research on AI in vocational education is based on an analysis of the latest theoretical approaches, practical applications of AI, and evaluations of its impact on learning effectiveness. To ensure a comprehensive study of the topic, a range of research methods has been employed.

A literature review on the use of artificial intelligence in education highlights the significant potential of this technology to enhance the learning process, ensuring personalized learning, increasing efficiency, and improving accessibility.

Adaptive learning systems can be utilized to create educational trajectories that best align with each student's knowledge level and learning style. Adaptive learning is both a scientific and technical achievement. Rapid feedback, correction, metacognition, and mastery-based learning are just some of the many educational benefits of this system [18].

The implementation of AI in Ukraine's educational system is regulated by several legal documents and supported by scientific research, which define strategies, opportunities, and challenges of this process.

In December 2020, the Cabinet of Ministers of Ukraine approved the Concept of AI Development in Ukraine, which identifies education as one of the priority areas for AI implementation. This document emphasizes the need to improve digital literacy, develop legal mechanisms for AI regulation, and integrate relevant technologies into educational programs [19].

The Ministry of Education and Science of Ukraine, in collaboration with the Ministry of Digital Transformation, has developed instructional and methodological recommendations for the use of AI technologies in general secondary education institutions. These recommendations aim to ensure responsible AI use, adhere to ethical standards, and increase educators' awareness of potential risks [20].

Researchers are exploring the potential of AI in personalized learning, automated assessment, and the creation of adaptive educational environments. For instance, Hrytsenchuk analyzes Ukraine's and other

countries' experiences in integrating AI into the educational process, as well as examining modern technologies such as expert systems, chatbots, and intelligent tutors [15].

Iliichuk substantiates the relevance of AI implementation in education, defines its role in improving learning quality, and outlines potential risks associated with its use [21].

Despite AI's significant potential in education, challenges remain regarding ethics, data privacy, and the need for teacher training in new technologies. It is crucial to maintain a balance between innovation and respecting the rights of educational process participants.

Thus, legal documents and scientific research provide the foundation for responsible and effective AI implementation in Ukraine's educational system, contributing to improved learning quality and student preparedness for contemporary challenges.

Various AI tools are applied in education to enhance the learning process and improve teaching efficiency. The choice of specific technologies depends on the field of study, specialization, and educational goals. This publication examines the most widely used AI tools actively utilized in the educational environment.

Adaptive learning systems such as Coursera and Khan Academy enable the creation of individualized learning paths for each student. Data analysis shows that students using adaptive platforms demonstrate higher knowledge retention levels compared to traditional methods.

AI-based virtual laboratories and simulations can significantly improve students' practical training. For example, in engineering, students can simulate equipment operation, conduct experiments, and analyze results without endangering equipment or the environment.

One such tool is Labster, a web-based platform offering virtual laboratory simulations in STEM subjects. Currently, over 168 simulations for high schools and 248 simulations for higher education institutions in biology, chemistry, physics, and related sciences have been developed. Labster requires a compatible device and stable internet connectivity. Each simulation provides an immersive first-person experience with realistic movements, voice guidance, and accessibility settings explaining each element on the screen [22].

The use of AI-powered chatbots and virtual assistants, such as ChatGPT, has become widespread for student consultations, answering course-related questions, and assisting with assignments. This facilitates prompt assistance and increases student satisfaction.

Nedashkivska [23] emphasizes the role of intelligent systems, including virtual assistants. Task-oriented bots simplify complex tasks, such as @topdf_bot, which converts documents and files (doc, docx, odt, txt, jpg, etc.)

into PDF format. Informational bots provide regular updates on specific topics.

A team of authors, including Vizniuk [24], highlights AI's role in knowledge assessment. Tools like Google Forms, AutoTutor, and other interactive platforms enable quick and objective student evaluations. Automated assessments reduce teachers' workload and provide detailed feedback.

The most straightforward applications of AI include knowledge assessment, automatic task monitoring, error detection and correction, and support for teachers in determining task completion independence when grading. Additionally, AI can mitigate academic dishonesty by analyzing video footage and user behavior in browsers. AI-based exam monitoring systems verify the independence of task completion. AI also aids in knowledge acquisition and skills development by recognizing text and speech, analyzing natural language, and facilitating understanding [24].

The Google Forms™ ChatGPT Quiz Generator offers a convenient way to create quiz questions. Using the latest GPT-4 model, the process is simple: input an article's text and click «Generate Questions.» GPT OpenAI will generate questions based on the provided text. Users can specify the number of questions, correct answers, and question types (multiple-choice, checkbox, or list) for the quiz. The GPT Test Generator for Forms™ allows users to edit generated questions before integrating them into Google Forms™, streamlining the quiz creation process for online courses, student testing, or knowledge assessment in specific disciplines [25].

Digital technologies are transforming resource management in all elements of the agricultural system, enabling management based on optimization, individual approach, justification, and predictability. One aspect of «smart» agriculture is the use of unmanned aerial vehicles for tasks such as creating electronic field maps, monitoring crops, evaluating performance, protecting agricultural lands, and applying pesticides to control harmful organisms [3].

AI technologies are also utilized to develop «soft» skills, such as time management, teamwork, and decision-making. For example, simulation games model real-life scenarios, teaching students to make informed decisions. For agricultural engineers, the game Farming Simulator 23 Mobile is a suitable tool [26].

This is the mobile version of a popular farming simulator that immerses users in modern farm management. Offering a realistic farming experience with a variety of machines, agricultural crops, livestock, and production processes, the game includes over 100 licensed machines from well-known brands such as John Deere, CLAAS, Case IH, and New Holland. Players can cultivate grain and vegetable crops or take care of cows, chickens, and sheep. They can participate in the full cycle of

agricultural production, from sowing seeds to selling finished products. Participants in the game can work together to achieve common goals. The game simulates weather dynamics, soil impact, and machine movement. It is adapted for mobile devices, available for iOS and Android, and features an intuitive interface for convenient management of all aspects of the farm.

Farming Simulator 23 Mobile enhances understanding of agricultural processes by familiarizing users with the full cycle of agricultural production, including planning sowing campaigns, crop care, and harvesting. Virtual operation of various agricultural machines provides insights into their functions and principles of operation. The game fosters analytical skills regarding the economic feasibility of crop cultivation and livestock farming. It also develops teamwork, collaboration, and task distribution skills. Additionally, it encourages independent decision-making, particularly in evaluating factors such as weather, sowing timing, and plowing. The visualization of theoretical knowledge enables students to observe realistic models of agricultural operations. Gamification makes the learning process more engaging and motivating for students. The game allows students to conduct virtual experiments without exposing themselves or real farms to risk. Integrating Farming Simulator 23 Mobile into educational programs enables the simulation of production processes, training in machinery operation, and assessment of the economic aspects of the agricultural business.

Research has demonstrated that the implementation of AI in vocational education is a promising direction that can enhance the quality of education and the preparation of qualified specialists. However, the effective use of these technologies requires appropriate technical support, teacher training, and the development of ethical guidelines for AI utilization. Future research prospects include improving AI technologies for vocational education, developing accessible tools for mass use, and studying their impact on training quality.

We conducted a survey among 45 teachers and 120 students regarding the use of AI in education and work. According to the results, the majority of students (approximately 70%) are already familiar with AI technologies, although their level of awareness varies. Students actively use tools such as chatbots, automated assessment systems, and adaptive learning platforms. Although less popular, virtual simulations are also used; however, their broader implementation requires infrastructure improvements.

Regarding the effectiveness of AI for personalized learning, most students (approximately 60%) consider these technologies highly effective. They emphasize that adaptive algorithms and assessment systems allow for a more individualized learning approach, which is particularly important in blended and distance learning environments. Students also have a positive attitude toward the use of AI in education, supporting its widespread adoption. However, some students express concerns about

the potential complete replacement of teachers by AI in the future. This indicates that while students recognize the importance of human factors in education and are willing to collaborate with technology, they are not ready for full automation.

Among teachers, the results show that only 40% actively use AI technologies in their pedagogical practice. This may be due to a lack of sufficient technical training or limited access to resources such as specialized platforms or software. However, the majority of teachers (approximately 35%) use these tools occasionally, employing automated assessment systems, adaptive platforms, and other innovative technologies to enhance the quality of education. Teachers particularly highlight the significant impact of AI on personalized learning. Most of them (55%) believe that AI can greatly improve the individual approach to students by adapting the learning process to their needs, knowledge level, and learning pace.

However, there are substantial barriers to the implementation of AI in teaching. The main challenges include insufficient technical training for teachers (60%), lack of funding (50%) for upgrading educational platforms, and ethical and legal issues related to student data usage and AI technologies (40%). Despite these challenges, teachers express a willingness to undergo additional training for better AI integration into their teaching, which is a positive sign for the future development of these technologies in education.

Overall, projections indicate that while AI tools are already being used by students and teachers, their implementation faces several significant challenges. Primarily, these are technical barriers, including inadequate teacher training and the lack of necessary software and infrastructure for effective AI use in education. Additionally, the absence of funding often hinders the implementation of innovative technologies in educational institutions. Despite these difficulties, both students and teachers recognize AI's vast potential for improving personalized learning and enhancing the efficiency of the educational process. Students express readiness to adopt new tools, while teachers show a desire to improve their skills in working with technology, which opens up prospects for AI's future integration into education.

The survey results demonstrate a high level of positive perception of AI in education among both students and teachers while also identifying existing challenges related to technical and financial aspects of implementing these technologies. To maximize the benefits of AI use, efforts should focus on improving teacher training, expanding access to resources, and developing ethical standards for AI utilization in education.

IV. CONCLUSIONS

Within the context of our research, the characteristics of AI usage in professional education have been identified. The study has outlined the prospects for further development of AI-based personalized learning and its

impact on the future of education. A survey conducted among educators and students has demonstrated a high level of interest in and usage of AI technologies in the learning process.

Based on the analysis of literature and survey data, it has been established that AI technologies facilitate the adaptation of the educational process to the individual needs of students, enabling the creation of personalized learning trajectories while ensuring interactivity and flexibility. AI-based virtual simulators and laboratories allow students to develop practical skills without causing harm to equipment or the environment. The implementation of automated knowledge assessment systems enables rapid and objective analysis of students' preparedness, reduces the workload on instructors, and enhances feedback, which can be used to improve the quality of education. Additionally, AI-powered chatbots and other systems can provide real-time assistance to both students and educators, promoting better knowledge retention and motivation.

Approximately 60% of students consider AI an effective tool for personalized learning, enhancing the individualization and flexibility of the educational process. At the same time, some students express concerns about the potential complete automation of education, emphasizing the importance of the human factor. Among educators, only 40% actively use AI in their work, indicating certain barriers to the adoption of these technologies. The primary challenges include insufficient technical training, lack of funding, and ethical and legal concerns regarding student data usage. Despite these difficulties, the majority of educators recognize the positive impact of AI on the personalization of learning and express willingness to undergo professional development in this area.

The practical value of the research lies in providing recommendations for the integration of AI systems into the educational process. Special attention should be paid to the ethical and organizational challenges associated with the implementation of AI in education. Insufficient technical training for educators, financial constraints, and data privacy issues remain key barriers to the full implementation of these technologies. However, the willingness of educators to enhance their qualifications and adapt AI tools to the learning process serves as a positive signal for the further development of digital technologies in the education sector.

The results of the surveys indicate that students are using AI tools more actively than educators and generally rate their effectiveness in learning positively. However, concerns regarding the potential automation of the educational process highlight the importance of maintaining a balance between technology and the human factor in teaching.

Prospects for further research include improving adaptive educational platforms, developing accessible tools

for the widespread integration of AI into the learning process, and evaluating its impact on the quality of student training. An especially important direction is the integration of AI into curricula to foster soft skills such as time management, decision-making, and teamwork, which will contribute to the development of competent specialists across various fields.

Overall, the study results indicate the significant potential of AI in education, particularly in the domain of personalized learning. However, for the effective implementation of these technologies, it is necessary to address issues related to the technical training of educators, ensure access to innovative educational platforms, and establish clear ethical and legal frameworks for AI usage. Resolving these challenges will contribute to the further integration of artificial intelligence into education and enhance its overall effectiveness.

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Model of Digitalization Professional Training of Future Vocational Education Teachers

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Abstract- Digitalization in higher education constitutes a fundamental vector of contemporary societal progress, reshaping traditional paradigms of pedagogy, research methodologies, and institutional governance. Within the global information landscape, digital technologies function not merely as facilitators of educational communication but as transformative agents that redefine knowledge acquisition, processing, and dissemination. The current phase of educational evolution is characterized by the proliferation of digital platforms, which significantly enhance accessibility to academic resources and foster flexible, adaptive learning environments. The integration of advanced digital technologies across all facets of the academic process underpins the digital transformation of universities. The adoption of digital tools necessitates a reconfiguration of conventional instructional methodologies, incorporating multimedia applications, interactive simulations, and immersive technologies such as virtual and augmented reality. These innovations serve to augment student engagement and align educational experiences with practical professional scenarios, particularly in disciplines where experiential learning is indispensable, such as pedagogy and engineering. Beyond instructional practices, digitalization exerts a profound influence on the organizational and administrative dimensions of higher education institutions. The implementation of automated management systems optimizes processes such as student enrolment, academic performance monitoring, and institutional communication. Concurrently, the integration of digital technologies within scientific research fosters interdisciplinary collaboration and enhances access to extensive electronic repositories, thereby amplifying the efficiency and scholarly impact of academic inquiry. The present study seeks to develop a comprehensive model for the

digitalization of professional training for future vocational education teachers. To achieve this objective, a comprehensive theoretical analysis of scholarly literature on educational digitalization was conducted, complemented by an empirical study employing a structured survey. The survey aimed to evaluate students' foundational digital competencies, the readiness of both educators and learners to integrate digital technologies into the educational process, and the primary challenges hindering this transition. The research utilized both quantitative and qualitative methods for data analysis to ensure a robust and multidimensional assessment of the findings. The findings serve as the foundation for the development of a structured model aimed at enhancing the digitalization of vocational education teachers, ensuring its congruence with contemporary educational imperatives.

Keywords- digital educational environment, digitalization, model of digitalization, vocational education teachers.

I. INTRODUCTION

Contemporary trends in education system reform and the active digitalization of the learning process necessitate the implementation of innovative approaches to the training of future specialists in higher education institutions. These advancements facilitate their adaptation to the demands of the modern educational environment and professional practice [1]. The integration of digital technologies enhances learning outcomes, increases students' motivation to solve complex problems, fosters a responsible approach to knowledge acquisition, and

Online ISSN 2256-070X

<https://doi.org/10.17770/etr2025vol3.8560>

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promotes the development of teamwork and collaboration skills.

The digitalization of professional training for future vocational education teachers is a crucial factor in improving the quality of education and ensuring graduates' competitiveness in the modern labor market. According to the Project Concept for the Digital Transformation of Education and Science for the Period up to 2026 [2], the primary objective of digitalization in education is to leverage digital technologies to optimize educational and scientific processes, automate various functions, and enhance accessibility and convenience for all stakeholders in the educational environment.

This concept outlines two fundamental directions of digital transformation, each specified through strategic objectives:

1. Effective integration of digital technologies into the educational process, which includes: the creation of an accessible and modern digital educational environment; the development of digital competencies among educational professionals; and the modernization of educational content in the field of information and communication technologies (ICT) in accordance with contemporary requirements.

2. Optimization of management, regulation, and monitoring processes, which involves: ensuring transparency, accessibility, and efficiency in educational and scientific services and operations; and guaranteeing the availability and reliability of data in the field of education and science.

The strategic goals of digital transformation in education are realized through a system of operational objectives that define specific directions for the implementation of digital technologies in both the learning process and educational management [2].

The strategic goals of digital transformation are implemented through a system of operational objectives. The realization of this Concept will have a positive impact on the development of the digital educational environment, facilitating the establishment of a robust digital infrastructure, enhancing the digital competencies of teaching and research staff as well as students, and promoting the creation of high-quality digital educational content. Additionally, it will support the automation and digitalization of regulatory and management processes, improve transparency and accessibility of educational services, increase the efficiency of digital technologies, and accelerate the overall process of digital transformation [2].

Digital transformation and higher education are interdependent domains that interact within the modern educational landscape, ensuring the preparation of specialists capable of adapting to the dynamic changes in society and professional practice. The rapid advancement of digital technologies necessitates the implementation of innovative approaches in higher education institutions aimed at fostering students' digital competencies, which are increasingly in demand in both the labor market and

everyday life. Simultaneously, educational institutions are actively integrating digital technologies into the learning process to enhance its efficiency, accessibility, and overall quality, while also expanding opportunities for all participants in the educational system.

The digital transformation of higher education represents a process of adapting academic institutions to the digital environment through the integration of information and communication technologies. This transformation encompasses not only the development of technological infrastructure but also the refinement of pedagogical and administrative practices to improve the effectiveness and efficiency of educational processes. Digital transformation is a fundamental prerequisite for modernizing the education system in response to contemporary challenges and opportunities, while also contributing to the enhancement of students' learning experiences and academic outcomes [3].

Digital transformation in higher education encompasses a broad range of technological solutions, including websites, e-books, social media, and online communities, as well as webinars, podcasts, and microblogging. Key components further include artificial intelligence, virtual and augmented reality technologies, and cloud computing. Additionally, online programs and educational platforms, learning management systems, and big data analytics play a crucial role in optimizing education by providing valuable insights and predictive capabilities. Among the latest trends, gamification, e-learning, video-assisted learning, blockchain technologies for secure student record storage, and immersive learning through virtual and artificial reality have emerged as significant advancements [4].

Scientific research findings have made it possible to identify a range of effective approaches to the digitalization of professional training for future vocational education teachers. These include the implementation of online courses and webinars for educators incorporating modern teaching and learning methods; the use of virtual reality (VR), augmented reality (AR), and artificial intelligence (AI) in the educational process; the development and active utilization of multimedia educational materials; the advancement of mobile learning to ensure a more flexible educational process; the formation of a modern digital educational environment within higher education institutions; the protection of data privacy and security in digital spaces; and the enhancement of digital competencies among educators. The digitalization of vocational teacher training contributes to improving education quality, professional training efficiency, accessibility, and effectiveness while also expanding opportunities for the innovative development of pedagogical practices [5].

An essential aspect of digitalization in vocational teacher education is the implementation of STEM education, which fosters the integration of science, technology, engineering, and mathematics. This approach promotes the development of critical thinking, creative

problem-solving, and digital literacy, which are essential for modern professional practice [6; 7; 8; 9].

In the context of digital transformation, higher education institutions must adapt their educational processes to emerging challenges and opportunities within the modern educational system. The successful digitalization of higher education institutions depends not only on their flexibility and adaptability but also on the effective integration of advanced digital technologies and innovative tools into the learning process [10].

At the same time, digital transformation should encompass not only technical modernization but also a fundamental reconfiguration of educational content. This is essential for equipping higher education students with contemporary competencies that align with labor market demands and contribute to the training of highly qualified professionals for the economy of the future.

The implementation of digital technologies in university activities offers numerous significant advantages, among which one of the most critical is enhancing accessibility to education. Digital learning platforms and distance education resources enable students to participate in classes without the necessity of physical presence, thus allowing for greater flexibility in structuring their learning process and adapting it to individual needs. Additionally, digital technologies introduce new teaching possibilities, making learning more interactive and engaging. For example, the application of virtual reality and educational simulations facilitates a deeper understanding of complex subjects and fosters the development of practically oriented skills [3].

The digitalization of education is implemented across several key areas:

- Ensuring access to digital technologies for students, educators, researchers, and administrative staff;
- Developing and integrating digital educational resources and platforms with support for interactive and multimedia content, ensuring open access for educational institutions and learners, as well as implementing automation tools for core educational and administrative processes;
- Designing and deploying innovative computing, multimedia, and digital learning tools, along with equipping educational institutions with digital infrastructure (e.g., multimedia classrooms, research STEM centers, virtual laboratories, inclusive learning environments, and blended learning classrooms);
- Providing high-speed Internet access (Fiber-to-the-Building and Wi-Fi models) in educational facilities at all levels;
- Expanding distance education through cognitive and multimedia technologies;
- Enhancing digital competencies and literacy among all participants in the educational process [11].

Despite the undeniable benefits of digitalization, researchers identify several challenges associated with this process. These include limited access to essential infrastructure and technical resources, insufficient training of instructors and students in the use of digital tools, as well as data security and privacy concerns [12].

II. MATERIALS AND METHODS

This study employed a comprehensive theoretical analysis of scientific literature on the digitalization of education and the transformation of professional training for future vocational education teachers. The analysis aimed to identify key trends, challenges, and opportunities associated with the integration of digital technologies into the educational process, thereby contributing to the advancement of pedagogical practices in vocational education.

In addition to the theoretical investigation, an empirical study was conducted using a structured survey developed by the authors. The survey was designed to examine students' perceptions of digitalization in education and its implications for their professional training. To ensure accessibility and efficiency, the questionnaire was administered via Google Forms.

The study sample comprised 60 students enrolled in a bachelor's degree program in specialty 015 «Professional Education» at Oleksandr Dovzhenko Hlukhiv National Pedagogical University and Yuriy Fedkovych Chernivtsi National University. The collected data were systematically analyzed to assess students' attitudes toward digitalization and their readiness to integrate digital tools into their professional training.

To analyze the survey results, both quantitative and qualitative research methods were applied. The quantitative analysis included the calculation of the percentage distribution of responses, determination of mean values, and correlation analysis between students' level of digital competence and their experience in using digital technologies. The qualitative analysis involved processing open-ended responses, which enabled the identification of key challenges in the digitalization of education, barriers to implementation, and students' needs for enhancing their digital skills. Furthermore, the analysis provided the basis for formulating recommendations to improve the effectiveness of digital technology integration in the training of future vocational education teachers.

Based on the survey findings, a model for the digitalization of professional training for future vocational education teachers was developed. This model synthesizes theoretical insights and empirical evidence, offering a structured framework for enhancing the digital competencies of prospective specialists in vocational education.

III. RESULTS AND DISCUSSION

To evaluate students' level of digital competence, their experience in using digital technologies in learning, and to identify barriers and opportunities for the digitalization of

the educational process, a questionnaire was developed. The survey comprises five sections, each designed to examine specific aspects of the digital training of future vocational education teachers.

The first section includes general questions aimed at determining respondents' demographic characteristics (age, gender, educational institution, and year of study) as well as assessing their access to essential digital equipment. The second section focuses on evaluating students' digital competencies, where respondents rated their proficiency in using digital platforms, cloud services, educational simulators, and cybersecurity fundamentals on a five-point scale.

The third section investigates students' practical experience with digital technologies in the learning process. It contains questions about their use of learning management systems (LMS) (e.g., Moodle, Google Classroom), participation in online courses, and engagement with virtual laboratories and other interactive learning tools. The fourth section assesses students' readiness for digital learning and their attitudes toward incorporating digital technologies into their future professional activities. Particular attention is given to barriers that may impede the digitalization of education, such as limited technical training, insufficient access to necessary equipment, and low motivation.

The fifth section examines students' expectations regarding the digitalization of education. Respondents were invited to share their perspectives on the effectiveness of various digital tools and propose strategies for enhancing the university's digital learning environment.

The study involved 60 students from the Specialization 015 «Vocational Education» at the Oleksandr Dovzhenko Hlukhiv National Pedagogical University and the Yuriy Fedkovych Chernivtsi National University. The results of the survey yielded the following findings:

General Information about the Respondents

The survey on the use of digital devices in learning revealed that most respondents have access to laptops or PCs (85%) and actively use tablets and smartphones (65%). However, only 10% of students have experience with VR/AR technologies or STEM laboratories, indicating insufficient implementation of innovative technologies.

Digital Competency Level

The level of digital technology proficiency was assessed on a scale from 1 to 5. The highest average ratings were given to platforms for distance learning (LMS), such as Moodle, Google Classroom, and Teams (average score – 3.9), as well as cloud services (Google Drive, OneDrive) – 3.7. However, the use of more specific tools, such as digital educational simulators and virtual laboratories, remains at a low level (average ratings of 2.8 and 3.2, respectively).

Experience with the Use of Digital Technologies in Education

The survey results showed that 90% of students regularly use digital resources in the learning process. Specifically, 70% of respondents have participated in online courses or webinars, 48.3% have worked with virtual laboratories or STEM technologies, and 23.3% have experience with VR/AR. These findings confirm a high level of student engagement with digital tools, although they indicate limited use of the most innovative technologies.

Readiness for Digital Learning

The majority of respondents (78.3%) expressed a willingness to actively use digital technologies in their future professional activities. However, there are significant barriers limiting the integration of digital tools into the learning process: insufficient technical preparation (60%), limited access to modern equipment (50%), and low motivation among both students and teachers (35%).

Expectations and Suggestions for Digitalization of Education

Students identified the most effective tools for digital learning. The most popular were LMS platforms (90%) and online courses (71.7%), but the use of virtual laboratories (58.3%) and VR/AR technologies (32.3%) remains secondary. Students also made suggestions for improving the digital infrastructure of universities, including the incorporation of mandatory courses on digital technologies in professional training (55%) and increasing practical sessions with VR/AR use (43.3%).

The data obtained indicates significant achievements in the development of digital competencies among students, but also highlights numerous obstacles to integrating modern technologies into the educational process. The main barriers include insufficient technical preparation, limited access to appropriate equipment, and a lack of motivation. Based on an analysis of the scientific literature and the survey results, a model for the digitalization of vocational training for future educators in vocational education was developed (Table 1). This model addresses these barriers and aims to enhance students' digital skills to improve the quality of professional education.

TABLE 1 MODEL OF DIGITALIZATION PROFESSIONAL TRAINING OF FUTURE VOCATIONAL EDUCATION TEACHERS

Model component	
Subcomponent	Subcomponent description
Digital infrastructure	
Innovative Computer Labs and Mobile Laboratories	Providing educational institutions with technological platforms for interactive learning, equipping them with mobile tablets and laptops that allow work from any location. Such laboratories should be integrated with various digital tools that support cloud storage and collaboration.
Integration of Emerging Technologies (VR/AR, STEM)	The creation of specialized training laboratories for working with VR/AR technologies, enabling students to simulate real

	educational and pedagogical situations.
Expanded access to online resources	Platforms for interaction with students, such as Google Classroom, MS Teams, Moodle, as well as integration with external cloud resources and virtual libraries, to ensure that students have access to the most up-to-date materials.
<i>Expected Outcome:</i> the creation of modern educational infrastructure will ensure uninterrupted access to digital technologies and platforms for both students and instructors, thereby fostering the effective mastery of cutting-edge technologies.	
Digital educational tools and platforms	
Interactive LMS Platforms	The use of multifunctional Learning Management Systems (LMS) such as Moodle, Google Classroom, MS Teams, and others, which enable the creation and delivery of online courses, automate assessment, and support interactive tasks.
Virtual Laboratories and Simulators	The use of platforms for creating virtual laboratories and STEM environments, allowing students to conduct scientific experiments and simulate pedagogical situations in a safe and controlled environment.
Mobile Applications and Gamification	The inclusion of mobile applications for smartphones and tablets that enable learning through gamified and interactive modules, enhancing student engagement.
Electronic Libraries	The creation and provision of access to electronic textbooks and educational materials through university libraries.
Online Platforms	Platforms like Coursera, Prometheus, EdEra, Udemy, edX, and others offer a vast selection of courses across various disciplines, enabling students to choose the most relevant and interesting courses. These platforms also provide access to materials from
	leading universities and experts worldwide. On such platforms, students not only study materials but also interact with course participants from different countries, fostering global exchange of experience and learning cultures.
<i>Expected Outcome:</i> the expanded use of digital platforms will enable students to navigate the learning process with ease and actively utilize various tools for implementing educational projects and assignments.	
Development of students' digital competences	
Professional Training with Digital Technologies	Teaching Specialized Subjects Using Digital Tools. Mastering professional digital systems and software (AutoCAD,

	3D modeling, automation systems, etc.). Utilizing cloud technologies for data processing.
Individual and Group Learning	Creating Conditions for Individual and Group Projects. Enabling students to explore and apply digital tools in developing educational materials and presentations.
Implementation of Innovative Approaches	Creating Conditions for Individual and Group Projects. Enabling students to explore and apply digital tools in developing educational materials and presentations.
<i>Expected Outcome:</i> students will be able to effectively utilize digital technologies for creating educational content and managing the learning process, enabling them to adapt to the demands of the modern digital world.	
Teaching methods and practical classes	
Blended Learning	Combining Traditional and Online Classes to achieve a more flexible learning approach, allowing students to choose the most effective methods for mastering the material.
Interactive Seminars and Training Sessions Using VR/AR	Students can engage in practical sessions where they work with virtual learning environments, develop their own projects, and test pedagogical strategies in conditions that simulate real-world scenarios.
Project-Based Learning	Involving students in the development of real educational projects that incorporate digital tools, where they create instructional programs, interactive courses, and multimedia materials.
Internships and Dual Education	Organization of online internships and apprenticeships in collaboration with educational institutions and enterprises. Use of electronic portfolios and digital reports. Interaction with employers through digital platforms.
Assessment of Learning Outcomes	The use of platforms for conducting online testing and examinations with automated assessment. Implementation of electronic grade books and academic records to track student performance.
<i>Expected Outcome:</i> students acquire practical skills in using cutting-edge technologies in real pedagogical settings, which helps them develop professional competence.	
Motivation and professional development of teachers	

Creating conditions for creative initiative	Motivating educators to use new pedagogical technologies through the organization of competitions and scientific conferences, where they can present their achievements in implementing digital technologies.
Developing digital culture	The implementation of courses on digital literacy fundamentals for students and educators. Training on information security basics and online ethics.
Collaboration with other educational institutions	Educators should actively collaborate with other universities, participate in international internships, and exchange experiences in the field of digital technologies. This will be supported by online conferences, webinars, and professional forums.
<i>Expected Outcome:</i> educators will have up-to-date knowledge of digital technologies, enabling them to effectively support students in mastering new tools.	

The development of infrastructure is a crucial stage in ensuring the successful digitalization of education. This requires the availability of modern equipment, high-speed internet connections, and powerful digital platforms that support learning at all stages of training.

Digital educational tools and platforms form the foundation for organizing the learning process, creating educational materials, and engaging students in independent work and project activities.

The development of students' digital competencies involves the formation of necessary skills for the effective use of digital technologies in professional activities. This also includes an awareness of the importance of cybersecurity and digital ethics.

The practical component is essential for integrating theoretical knowledge and skills into real pedagogical practice. This component focuses on actively involving students in the use of new technologies through practical classes and projects.

The professional development of teachers is crucial for ensuring the successful digitalization of education, as they must be motivated to continuously improve their skills and implement the latest technologies into the learning process.

IV. CONCLUSIONS

The conducted study has substantiated the necessity of digital transformation in the professional training of future vocational education teachers. The proposed model of digitalization integrates key components, including the development of digital infrastructure, the implementation of educational technologies, the enhancement of students' digital competencies, and the professional development of educators. This approach ensures a systematic and comprehensive transition to a technology-driven educational environment.

The research findings indicate that while students demonstrate a relatively high level of digital competence in utilizing Learning Management Systems (LMS) and cloud-based services, the application of more advanced technologies such as virtual and augmented reality (VR/AR) and digital educational simulators remains limited. The primary challenges identified include insufficient technical preparation, restricted access to modern digital equipment, and a lack of motivation among both students and instructors.

The developed model for the digitalization of vocational teacher education aims to bridge these gaps by promoting the integration of cutting-edge digital tools into the learning process, enhancing students' engagement through interactive and immersive technologies, and fostering the continuous development of digital competencies. Special attention is given to the introduction of STEM education as a means to cultivate critical thinking, problem-solving abilities, and adaptability to technological advancements.

Furthermore, the study highlights the importance of adaptive learning strategies, combining traditional and digital methodologies through blended learning, virtual laboratories, and project-based learning. The findings emphasize the need for institutional support and investment in digital infrastructure, ensuring a seamless and accessible digital learning environment.

Digitalization of vocational teacher education serves as a fundamental factor in improving the quality, accessibility, and efficiency of professional training. Its successful implementation will contribute to preparing highly qualified specialists capable of navigating the evolving landscape of digital education and addressing contemporary educational challenges.

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Features of the Application of Artificial Intelligence in the Formation of Creativity in the Professional Training of Teachers

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Abstract— Artificial intelligence (AI) is rapidly changing the educational landscape, opening up new horizons for the development of creativity and professional competence in the training of future teachers in the specialty A5.39 (formerly 015.39 “Vocational Education (Digital Technologies)”). Given the dynamic development of information and communication technologies (ICTs) in the modern world, it is important to study the impact of these changes on the educational process. Modern informatization of education has changed the role of the teacher as a knowledge carrier to a facilitator of learning. A modern teacher should not only be a translator of knowledge, but also an innovator, communicator, scribe, creator, tutor, coach, methodologist, and researcher. Students have access to a lot of information resources, and their role in the educational process is becoming more active. At the same time, new challenges arise due to data security and privacy. Innovative technologies, traditional, distance, online and hybrid learning models, digital platforms, interactive tools and adaptive systems contribute to a more individualized approach to the organization of the educational process. The authors of the article discuss tools and technologies that, with the support of AI (ChatGPT, Gemini, Claude, Leonardo, LearningApps, Tinkercad, etc.), including Python and Arduino robotics kits, contribute to the development of creativity and professional competence of future teachers. The use of such technologies in the educational process stimulates innovative forms of thinking, creativity, and teamwork among students majoring in A5.39. AI libraries (TensorFlow, PyTorch, etc.) allow future teachers to dive into the world of AI without requiring deep programming knowledge. Integrating AI, Python, and Arduino into teacher education stimulates creativity, develops professional competencies, and prepares future teachers for the challenges of modern education. Hybrid learning models, where technological tools are combined

with pedagogical innovations, form competent, creative and self-confident professionals capable of working in the digital age.

Keywords— artificial intelligence; innovative tools and technologies; creativity; professional training; hybrid learning; pedagogical technologies.

I. INTRODUCTION

In the modern world, information (digital) technologies and education are closely intertwined. The rapid development of information and communication technologies (ICT) has significantly influenced the organization of the educational process in higher education institutions (HEIs). Informatization of education has led to the transformation of traditional educational processes, which requires rethinking the roles of teachers and students. Teachers, who used to be the main source of knowledge, are now becoming learning facilitators who promote critical thinking, independent information search and self-education. We can note that students, having access to unlimited information resources, are becoming active participants in the educational process, which requires a high level of digital literacy [1].

Digital technologies can help in learning, but they cannot replace important social aspects of a person's need for live communication, emotional coloring, and non-verbal content of the educational process. On the other hand, the presence of digital tools in education creates challenges related to data security and privacy. As more and more data is collected and stored digitally, the risk of misuse of information is becoming increasingly high. An educational institution must ensure data protection and

Online ISSN 2256-070X

<https://doi.org/10.17770/etr2025vol3.8533>

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teach students how to use digital resources safely. Higher education institutions in Ukraine are required to implement and use complex information security systems (IPS) in their activities. In accordance with the Laws of Ukraine "On Information", "On Protection of Information in Information and Telecommunication Systems", "On Protection of Personal Data", comprehensive information protection systems in the information and telecommunication system are to be created in accordance with ND TZI 3.7-003-05, approved by the order of the Department of Special Telecommunication Systems and Information Protection of the Security Service of Ukraine. In May 2024, the Ministry of Digital Transformation of Ukraine published draft recommendations on the use of artificial intelligence in school education, which all schools should familiarize themselves with within a year.[2] Academician R. Gurevych and co-authors note in their research that AI in education is of great importance, especially in creating "individualized learning plans, automating task checking, adaptive testing, and even supporting teachers in assessing and analyzing student performance. AI provides powerful tools for analyzing educational data" [3]. The authors believe: "Artificial intelligence can become an important tool in the field of education, and using its capabilities, it is possible to adapt curricula to the individual needs of students by analyzing their progress, performance, and learning styles." We would like to note that informatization in education allows automating routine processes, which not only facilitates the work of teachers but also makes the educational process more interesting for students and teachers themselves. However, successful implementation of the latest technologies and innovations requires educational institutions to be ready for rapid change and adaptation. It is in the context of the rapid integration of digital technologies, artificial intelligence, and innovative approaches to the organization of the learning process that the issue of developing creativity arises, which would help all participants in the educational process to adapt to these challenges. We believe that a modern creative teacher will be able to find original solutions in teaching, develop interactive and exciting classes that will stimulate students' interest and promote cognitive activity and their active involvement in the educational process. In our opinion, developing creativity in future teachers helps to develop critical thinking skills, self-expression, and innovative problem-solving, which are important for a successful career in the professional future. Therefore, educational and professional programs should contain elements that promote creativity: project activities, interdisciplinary approaches, use of modern technologies, etc. To describe the impact of artificial intelligence and digital technologies on the formation of creativity and professional training of teachers, to give examples of the effective use of such technologies in the process of training future teachers. The innovation and information society, the digital society require the formation of a creative personality prepared to work in the era of innovation, mastering the necessary skills and competencies, ready to constantly update professional knowledge and skills. Today, creative education is being

formed in the world, which contributes to the achievement of more effective global indices of creativity, innovation, human development, freedom of economic development, etc. Sunil Gupta, a professor at Harvard Business School, analyzed Fortune 500 companies and studied Ukraine's indices, which are shown in Table 1.

TABLE 1. UKRAINE'S INDICES

No. p/n	Name of the Transformation Index of Ukraine	Rating place in the index
1.	Creativity	45
2.	Global Innovation Index	64
3.	Patent activity	27
4.	Human development	81
5.	Economic freedom	81

Gupta gives examples and analyzes them in detail, provides practical and effective advice on the path of inevitable digitalization, which allows us to take full advantage of all the opportunities offered by the modern world, as noted in Ukraine 2030. The Doctrine of Balanced Development [4]. In the context of the formation of the creative education model, new types of human-society interaction are emerging, which have led to the emergence of new forms of communication related to digitalization processes.

Creativity is an important competence for future teachers, as it allows them to implement innovative teaching methods that meet the needs of the modern world. According to O. Honcharenko (2019), creative teachers are able to create incentives for students, which leads to increased motivation and academic performance. The ability to use creative approaches also contributes to the development of students' critical thinking and independence. Creativity in teacher education is defined as the ability to generate new ideas and solutions, adapt to changing learning environments, and use resources effectively. According to T. Yakovyshyna (2019), creativity consists of several components: originality, flexibility, understanding of the context, and critical thinking ability (see Figure 1). The structure of creativity includes cognitive, emotional, and social aspects that form a holistic view of a teacher's personality.

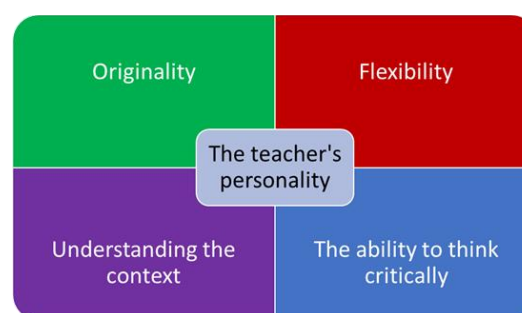


Fig. 1. Components of creativity.

Previous research has shown that students' creativity is influenced by individual traits Cheng (2019), educational environment Al-Kumaim (2021), and social support Lagüa (2019) [5], [6].

The leadership of university teachers is student-centered, action-oriented, and has a positive impact on students Liu (2023). At this stage, students are experiencing a peak period of knowledge acquisition, while facing many new challenges and opportunities. Both external and internal factors influence students' creativity Zhang (2022). The internal factors that influence creativity include personality, psychological capital, self-esteem, cognitive style, emotions, creative motivation, education, work experience, experience and skills, and growth needs Wang (2016). Psychological capital is significantly positively correlated with the creativity of corporate employees Choi & Chang (2014), Ravaji & Golouzan (2016). Huang and Luthans (2015) found that software engineers' psychological capital mediates the relationship between learning goal orientation and creativity [6]. In addition, both empirical studies and meta-analyses have found a significant positive correlation between students' self-esteem and creativity; however, this correlation is influenced by creativity orientation Deng & Zhang (2011), Fan (2012). Researchers have shown that positive psychological capital and self-esteem influence creativity. Researchers believe that creativity can be developed and is influenced by a variety of factors. It is important how the spiritual leadership of teachers (external factor) and positive psychological capital and self-esteem of students (internal factors) jointly affect the creativity of students. This combination of internal and external factors can further deepen the study of the mechanism of influence on the creativity of future teachers. The concepts of spiritual leadership, positive psychological capital, and self-esteem have attracted considerable attention from scholars and are considered to be closely related to individual creativity Wang (2021), Yazdanshenas & Mirzaei (2022), Zeng (2022) [7].

Studying the creativity of our time, J. Xu considers it a key competence in modern society that is crucial for personal growth and future career development of students. There are many internal and external factors that influence students' creativity, but the researcher is exploring a new, more detailed theoretical framework that considers the mechanism of influence of teachers' spiritual leadership on students' creativity. Among the internal factors affecting students' creativity, J. Xu notes that psychological resources are particularly important, so he chose two variables - positive psychological capital and self-esteem - to study the dual mediating effect on the relationship between spiritual leadership and students' creativity [8].

II. MATERIALS AND METHODS

The rapid development of information (digital) and communication technologies has contributed to the development of the teacher's professional crisis S. Loboda (2023). A teacher today is perceived as a person with many roles, which requires adaptation to new conditions.

Agreeing with the statements of S. Loboda, we note that in the dimensions of socio-pedagogical requirements for the advanced development of the innovation space in the modern educational sphere, the key factor remains the creative teacher [9].

Studying the impact of innovative technologies on the educational process, V. Fedorets proves that the use of digital platforms, interactive tools, adaptive systems, and hybrid learning models contribute to the effective organization of the educational process. When a person interacts with AI, the authors identify seven types of cognitive phenomena that arise: orientation- cognitive, subject-cognitive, communicative-cognitive, cognitive-analytical, cognitive- hermeneutical, cognitive-ontological, and cognitive-creative. Each of these types reflects different aspects of intellectual activity, including creativity. The cognitive-creative type of interaction is actualized through creative thinking, intuition, and the integration of various cognitive strategies. The authors emphasize that AI can stimulate creativity by providing new tools for generating ideas, interpreting data, and solving complex problems. The researcher emphasizes that AI can be a powerful tool for developing creativity, especially in the educational process. However, to fully utilize this potential, it is necessary to further integrate AI into curricula and actively engage students in using these technologies for creative tasks [10]. Creativity, as one of the key aspects of interaction with AI, can be an important factor in preparing future teachers to work in the digital era.

In 2023, a group of scientists K. Livingston, C. O'Sullivan, and K. Attard investigated the traits and conditions that foster teacher innovation in different international contexts. The study was conducted in different countries, where the main focus was on creativity as a key element of an innovative approach to education. Teachers presented various practices, new teaching methods that help develop creativity, as well as conditions for supporting a creative educational environment. how creativity in learning can positively influence the educational process, motivating students to actively participate and develop their own creative abilities [11].

The researcher H. Dewaard calls for a deliberate focus on media and digital literacy, as well as technological competencies in teacher education, based on her own experience as a teacher educator in Canada. As a teacher of pedagogical disciplines at the Faculty of Education, she argues that it is necessary to be fluent in media and digital skills in your educational practice. The researcher is convinced that practicing teachers should use technological resources to accomplish their tasks. It is becoming increasingly important to share the experience of practitioners, researchers and theorists in the field of education, making explicit what is often tacit and unexpressed, as well as sharing knowledge, reflections and actions [12]. By actively expressing their thoughts through blogs (Fig. 2), social media, and open scholarly publications, educators can publicly share details of what they do, how they do it, and why they do it.

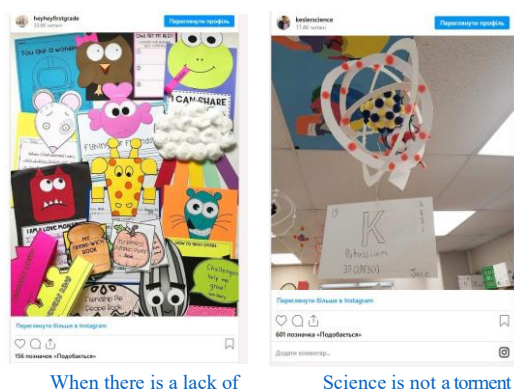


Fig. 2. A sample of Instagram educational blogs

We have studied the experience of K. Livingston, C. O'Sullivan, and K. Attard in their book "Characteristics and Conditions for Innovative Teachers: International Perspectives" where they describe the study of teachers' creativity through a comprehensive approach that included a variety of methods to obtain both quantitative and qualitative data [11]. One of the main tools was quantitative research, which included surveys and questionnaires of teachers. This made it possible to collect statistical data on their creative skills, preferences in choosing teaching methods, and readiness for innovation. Such studies allow us to assess the overall level of creativity among teachers, as well as to identify trends that characterize their approach to teaching.

However, qualitative research methods were used to gain a deeper understanding of how teachers perceive creativity and what conditions contribute to its development. In particular, interviews and focus groups with teachers allowed us to identify their personal practices, experiences and challenges they face in the process of integrating creative approaches into teaching. Such studies help to understand how teachers assess their own creativity, what strategies they use to develop it, and what factors are most important to them in this process.

Case studies have become another important tool for analyzing creativity. Researchers have looked at specific examples of successful innovative practices in different educational systems, which has helped to identify which methods and strategies are most effective in fostering creativity in both teachers and students. These cases demonstrate how certain approaches, such as project-based learning, cross-disciplinary integration, or the use of digital technologies, can become catalysts for the development of innovative thinking.

Classroom observation also played an important role in the study. The researchers were able to directly assess how teachers integrate creative methods into the learning process, what tools they use, and how this affects student engagement and interest. This approach allowed them to get an objective picture of how creativity manifests itself in a real learning environment.

In addition, a comparative analysis of the educational systems of different countries has revealed common characteristics that foster creativity. This made it possible to understand which conditions, such as support from the administration, access to resources, and professional development opportunities, are most important for the formation of innovative teachers.

In general, research has confirmed that developing teachers' creativity requires systemic changes in education. This includes not only support from educational institutions, but also providing teachers with the necessary resources, access to modern teaching methods, and opportunities for continuous professional development. Only under these conditions can an environment be created that will foster innovative and creative teachers who are able to prepare creative future teachers for the challenges of the modern world.

In the future, we can predict a significant spread of innovative technologies in the educational process, which will facilitate more effective interaction between teachers and students and open up new opportunities for achieving high learning outcomes. In particular, the use of artificial intelligence in education can be a powerful tool for developing the creativity of students, especially in the context of professional training of future teachers. In our study, we propose to integrate AI into curricula, which will stimulate creative thinking and innovative approaches to solving pedagogical problems. This may include the use of AI to create individual learning paths, automate learning outcomes assessment, and develop interactive tasks that develop students' critical thinking and creativity.

We believe that an important factor in obtaining high-quality professional education and professional and personal development of students as future professionals for the sustainable development of the state is the effective interaction of professionals with society. An important factor in the development of professional skills and abilities, as well as personal qualities such as responsibility, initiative, creativity, etc. contribute to the effective interaction of a professional with society [13]. An equally important factor in shaping creativity in teacher training is the skillful and appropriate use of artificial intelligence (AI) and its products. AI plays an important role in encouraging students to think critically, analyze and evaluate information. It is with the help of artificial intelligence that it is possible to automate the solution of similar problems, make decisions and solve tasks in real or virtual situations, which contributes to the development of their critical and creative potential. One of the possibilities of using AI is individualized learning. This technology makes it possible to develop educational and professional programs that take into account the individual needs and level of training of each student, which allows them to study the material at their own pace, ensuring more efficient knowledge acquisition [14].

The quarantine of 2019-2022, global circumstances (which favored online learning), as well as the rapid development of information technology and the expanding

influence of AI on all spheres of life, directly affect the way we teach and learn. The educational environment is also changing dynamically, and it is clear to everyone that the classical model of university education and the lecture as one of its most important components can be significantly transformed or even changed beyond recognition. Students need more than just passive perception of information - a model that is much more effective is one where students become direct participants in the lecture, participating in discussions and having the opportunity to respond to what they hear. In situations of relative chaos, during the war, Ukraine is actively implementing a hybrid (blended) learning system. Hybrid and blended learning have a common feature. It is the use of modern computer and mobile technologies that facilitate the learning process for both children and adults. For each, the material is presented in an accessible form that meets individual needs. When conducting blended or hybrid learning, different curricula are used to facilitate the receipt and transfer of information [12]. The most common platforms for organizing blended (hybrid) learning are Blackboard and Moodle. Students have the opportunity to communicate with teachers remotely, solve test tasks, work on materials independently, and have access to video lectures. In our opinion, this combination of technological tools and pedagogical innovations can help to develop competent, creative and self-confident professionals capable of working in the digital era. We would like to note that blended and hybrid learning not only meets modern challenges, but also opens up new horizons for creativity in education. The integration of traditional and new teaching methods contributes to the formation of an innovative educational process, which is critical in the face of rapid change.

Hybrid learning has a number of advantages that make it attractive to many students and teachers. The main advantages are flexibility, which allows students to choose a time and place for studying that is convenient for them. Individualization of learning, the ability to tailor the process to one's own needs and pace, significantly increases the efficiency of learning. The use of various teaching methods, such as videos, interactive tasks and forums, makes the learning process interesting and rich. In addition, saving time and resources by not having to attend classes physically saves travel time and transportation costs. Finally, the ability to review lectures and materials repeatedly allows students to better absorb the information.

However, hybrid learning also has its drawbacks. The lack of direct contact with the teacher and fellow students can negatively affect motivation and the quality of learning. Dependence on technical means and an Internet connection can create obstacles in the learning process, in particular when technical problems arise. Students need a high level of self-discipline and self-organization to succeed in their studies, which is not always easy to achieve. Some subjects requiring practical skills are difficult to study effectively in an online format. Also, ensuring fair and objective student assessment can be challenging in an online environment.

One of the hybrid learning technologies is the use of the project method, which involves working on real-world problems and tasks. This method allows both teachers and students to go beyond traditional learning by developing the ability to analyze, synthesize, and creatively solve problems. Project-based learning not only increases the motivation of students but also prepares them for life challenges where they need to apply knowledge in practice.

An important element of modern education is cross-disciplinary learning, which integrates knowledge from different subjects into a single learning context. This approach helps teachers create a more connected and engaging learning environment where students can apply their knowledge in new, non-standard situations. For example, combining science, technology, arts, and humanities allows future teachers to see interdisciplinary connections and develop a deeper understanding of the world around them. It also promotes systems thinking, which is essential for success in modern society. In addition to cross-disciplinary learning, interactive methods such as games, simulations, and other innovative technologies can be used to play a key role in engaging students in the learning process. They not only make learning more exciting, but also stimulate creativity, activity, and independence of students. For example, the use of simulations allows students to "live through" complex situations, developing decision-making and critical thinking skills. Games, on the other hand, promote team spirit and the ability to respond quickly to change. Games require cooperation and teamwork, which is another important aspect of modern education. Working in groups allows future teachers to exchange ideas, learn from each other, and develop collective creativity. This not only increases the effectiveness of learning, but also prepares students for future professional activities where teamwork is one of the key skills. Teachers who encourage collaboration create a learning environment where each participant in the educational process can feel part of the team and contribute to the overall result.

III. RESULTS AND DISCUSSION

The integration of digital technologies into the educational process opens up new opportunities for students' creative expression. The use of multimedia tools such as video, audio, graphics, and interactive platforms allows students to create their own projects, presentations, and other works that demonstrate their knowledge and skills. Digital technologies also allow teachers to individualize the learning process, taking into account the needs and abilities of each student.

The digitalization of modern life and education in particular is forcing more and more attention to be paid to the integration of innovative technologies that promote the development of creative thinking, team spirit, and practical skills. In our study, we have reviewed such tools as ChatGPT, Gemini, Claude, Leonardo, LearningApps, Tinkercad, as well as robotics kits based on Python and Arduino. These tools not only help in teacher training, but also encourage teachers to use the latest teaching methods.

These tools open up new opportunities to develop creativity, teamwork, and practical skills for both teachers and future teachers.

Artificial intelligence, represented by ChatGPT, Gemini, and Claude, is becoming an indispensable assistant in the work of teachers. It allows you to work efficiently with large amounts of information, automate routine processes, such as the creation of training materials, and develop individual approaches to learning. For example, ChatGPT can be used to create interactive dialogues that simulate real-life teaching situations, which helps to better prepare for working with students. In addition, this tool can generate ideas for projects, which stimulates creative thinking and an innovative approach to learning. Artificial intelligence allows you to create adaptive educational platforms that analyze the level of knowledge of students, recognize their needs, and provide personalized recommendations. For example, machine learning algorithms can be used to identify weaknesses in understanding the material and automatically suggest additional learning resources or exercises. This not only improves the quality of education, but also allows teachers to allocate their time more efficiently, focusing on individual student support. Integration of AI into the educational process also allows automated assessment, which significantly reduces the workload of teachers. Text analysis algorithms can check written works for compliance with predefined criteria, and image processing systems can be used to evaluate drawings or handwritten assignments. Gemini and Claude, in turn, help with data analysis, which allows educators to better understand the needs and abilities of each student [3]. This makes it possible to adapt the educational process by creating personalized lesson plans, tests, and exercises that develop critical thinking of students.

An important element of modern learning is the visualization of complex concepts, and this is where the Leonardo tool comes in. It allows you to create high-quality visuals such as charts, infographics, and presentations that make it easier for students to understand information. Teachers can use Leonardo to illustrate complex topics, making learning more accessible and interesting. For example, when studying scientific concepts or historical events, visuals help students to better understand the material and visualize key aspects of the topic.

Interactive platforms such as LearningApps, Kahoot, Mentimeter play an important role in creating an engaging learning environment. These platforms allow you to develop interactive exercises, tests, and games that engage students in active learning. For example, you can create individualized tasks that take into account the level of knowledge and interests of each student. This not only increases motivation to learn, but also promotes independence and responsibility.

Tinkercad is an indispensable tool for developing spatial thinking and design skills. This 3D modeling platform allows future educators to create their own models that can be used in robotics projects. Teachers can integrate

Tinkercad into the educational process by offering students tasks related to the development of prototypes of devices or architectural objects. This not only develops technical skills but also stimulates creativity in problem solving.

We would like to elaborate on a practical lesson using 3-D modeling with future teachers. In the classes at Vinnytsia Mykhailo Kotsiubynskyi State Pedagogical University, modern approaches are being actively implemented as part of the curriculum of the mandatory discipline "Technology Workshop" for future technology teachers. One of the key elements of training is the use of computer graphics and 3D programs for product design, which significantly increases the efficiency of the educational process and develops students' creative and technical skills. Previously, the design process involved manual drawing on paper, calculations, and the creation of working models, which took a lot of time and effort. Now, thanks to modern computer programs, students can immediately see the project in three projections (see Figure 3), in volume, and make adjustments quickly, which significantly saves time and improves the quality of work.

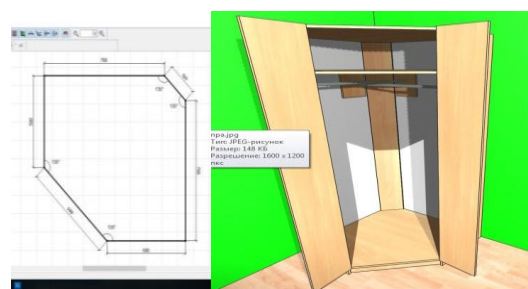


Fig. 3. 3-D design of a wardrobe for clothes corner closed two-door (student development)

Among the variety of programs for computer-aided furniture design, we have chosen the most effective and convenient program for use in the educational process - PRO100. It allows you to quickly and efficiently develop designs, estimate the cost of materials, obtain detailed drawings, and visualize projects. The PRO100 program consists of subprograms such as PRO100 Professional, PRO100 Show Room, and New Cut, which provide ample opportunities for creating complex projects. For example, through the Structure window, you can analyze any element of the project in detail, quickly edit or replace parts using ready-made libraries, and get detailed drawings and specifications. PRO100 automates many processes, such as marking holes, marking parts, taking into account the technological nuances of connecting elements, placing fittings, and generating optimal cut maps. This makes it an ideal tool for teaching future technology teachers who can quickly master design skills and achieve high results in furniture design.

During the technological workshop, students perform laboratory and practical work where they apply their knowledge in practice. For example, one of these works is "Development of a project for a corner wardrobe for clothes using the PRO100 computer-aided design (CAD) system." The purpose of this work is to teach students how to design

custom furniture using modern computer-aided design tools. According to the instructions, , future technology teachers work through theoretical issues, prepare sketches, approve them with the teacher, and then proceed to create a project in the PRO100 program. They group the parts, give them texture, save the project in the library, and prepare a report with the results of their work.

This approach allows students not only to master the technical skills of working with the program, but also to develop creative thinking and the ability to innovate in solving problems. The use of PRO100 in the educational process has proven to be effective, as future technology teachers demonstrate a high level of learning and the ability to create complex projects on their own. This indicates that the integration of modern technologies into the training of technology teachers is an important step in the development of education, which allows training specialists who can work effectively in the context of modern technological progress.

Robotics and programming is an important area in modern education. The use of robotics kits based on Python and Arduino allows students to develop programming, logical thinking, and teamwork skills. Python, as one of the most popular programming languages, is used to develop algorithms and control robots. Arduino, in turn, allows you to create simple and complex electronic devices that stimulate creative thinking and engineering skills. Teachers can use these kits to conduct hands-on activities where students can create their own projects, such as automated systems or robotic devices. This not only develops technical literacy, but also builds the ability of future teachers to think innovatively and solve complex problems. This analysis visualizes the possibilities of using the Arduino platform and Python libraries to create robots that can be implemented in education and everyday life. The authors have presented a working model of a robot built and programmed on the basis of Arduino components to measure humidity in computer laboratories and develop automatic plant irrigation systems to maintain appropriate conditions in classrooms. They also provide an example of integrating the learning of the Python programming language with the use of Arduino robotics kits. This method aims to enhance the quality of training for future computer science teachers, broaden their methodological toolkit, and equip them with the ability to teach students using innovative methods. The study's results and the developed teaching materials aim to increase students' interest in STEM education and prepare a new generation of computer science teachers for the challenges of the modern technological world. This will expand their methodological arsenal and develop their ability to use integrated technical, engineering, and mathematical solutions to solve theoretical and practical problems [15].

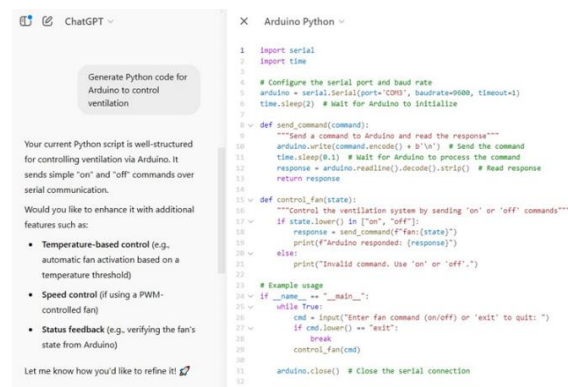
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3
4 # Налаштуйте порт і швидкість передачі даних
5 arduino = serial.Serial(port='COM3', baudrate=9600, timeout=1)
6 time.sleep(2) # Зачекайте, поки Arduino ініціалізується
7
8 def send_command(command):
9     """Відправка команди на Arduino"""
10    arduino.write(command.encode() + b'\n')
11    time.sleep(0.1)
12    response = arduino.readline().decode().strip()
13    return response
14
15 # Приклад використання
16 if __name__ == "__main__":
17     while True:
18         cmd = input("Введіть команду для Arduino: ")
19         if cmd.lower() == "exit":
20             break
21         response = send_command(cmd)
22         print(f"Arduino відповів: {response}")
23
24 arduino.close()
25

```

Fig. 4. Python code for Arduino generated by AI

Creativity is an integral part of teacher training, as it allows for innovative teaching methods and adaptation of teaching to different learning styles. With Python and Arduino, you can create unique educational projects that combine programming, robotics, and artificial intelligence. For example, you can develop educational robots that respond to voice commands or emotion recognition systems that help analyze students' moods during classes. With the help of Arduino, you can create smart classrooms that analyze the conditions of the learning environment, adjusting the level of lighting or ventilation according to the needs of students, which helps to increase their concentration and productivity. This opens up new possibilities for interactive learning, making it fun and effective.



The screenshot shows a ChatGPT chat window. On the left, the user's prompt is: "Generate Python code for Arduino to control ventilation". Below this, there is a summary of the current Python script, which is described as well-structured for controlling ventilation via Arduino, sending simple "on" and "off" commands over serial communication. The user asks for enhancements and lists three suggestions: temperature-based control, speed control using PWM, and status feedback. The right side of the screenshot shows the Python code generated by the AI, which includes imports for serial and time, a function to send commands, and a main loop that takes user input and sends commands to the Arduino.

Fig. 5. Code generated by AI according to the promo

We conducted a survey in the "Questionnaire: AI Pros and Cons" in Google form among students of two higher education institutions: Mykhailo Kotsiubynskyi Vinnytsia State Pedagogical University and Pavlo Tychyna Uman State Pedagogical University.

Fig. 6. Registration form "Questionnaire: AI pros and cons"

This survey revealed a number of challenges related to the use of AI in the educational process. In particular, it was found that most students demonstrate an initial level of interest in using artificial intelligence, but the creative potential of this technology remains underutilized. Only a small part of students actively use AI to perform creative tasks, which indicates the need to further improve the methods of integrating technology into the educational process.

Along with numerous advantages, the use of AI and other innovative technologies in education has certain limitations. One of the main challenges is the decrease in personal interaction between teachers and students, which can negatively affect the latter's motivation. This underscores the need for a creative approach to organizing the educational process that would combine the benefits of technology with the support of personal communication. For example, the use of hybrid learning formats, where online resources are supplemented by regular meetings and discussions, can be an effective solution to overcome this limitation.

IV. CONCLUSIONS

Creativity is a critical component of the professional activity of educators, which directly affects the quality of education and the development of students. Its formation requires the creation of a favorable environment in educational institutions, opportunities for professional development of teachers and active cooperation between them and students. Modern teachers must demonstrate high adaptability and flexibility, the ability to change their teaching approaches in accordance with the needs of students and the current challenges of society [16].

The integration of modern technologies, including artificial intelligence, into the educational process plays an important role in stimulating the creativity of future teachers. The use of AI tools allows educators to introduce new teaching methods, create individual learning paths, and automate routine processes, which, in turn, contributes to the development of innovative, creative thinking in both

teachers and students. In addition, cross-disciplinary approaches and cooperation between teachers and students of different educational and professional programs ensure the comprehensive development of the educational process, which is important for the formation of creative skills.

The use of various media materials, such as videos, audio recordings, and graphic elements, makes educational material more accessible and understandable. Visualization of information makes it easier to perceive and memorize, which is especially important in the process of forming future teachers' professional development. Interactive elements such as online tests, polls, and discussions on hybrid (blended, distance) learning platforms encourage students to actively participate in the educational process, creating a dynamic environment for sharing opinions and receiving instant feedback.

Experimentation with different forms of learning, including blended and hybrid learning, allows students and their teachers to choose the most convenient format for them, which promotes independence and creativity. The availability of learning resources anytime and anywhere allows students to plan their learning independently, increasing their motivation and engagement. In addition, the implementation of practical tasks, for example: 3-D modeling, programming Arduino in Python, using ChatGPT, Gemini, Claude, Leonardo broadens students' horizons and develops their professional competencies.

We believe that further research should focus on the impact of AI on the development of creativity in different educational contexts, including inclusive education, and the impact of AI on the psychological and cognitive state of future teachers in the process of professional training. It is also important to study the effectiveness of using various AI tools, such as content generators, data analysis systems, and interactive platforms, in developing students' creative and professional skills. The development of new methods of integrating AI into the educational process that combine technological innovations with support for personal interaction may be an important area for future research [17].

Thus, the use of AI will create an environment where teachers and students can effectively interact, develop their skills, and reach new heights in their professional activities.

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Using AI Tools for Personalising Learning in the English Language Classroom: Computer Science Undergraduate Students' Perceptions

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Abstract—Up-to-date higher education in general and foreign language training, in particular, require skilled university teachers and the possibility to use the latest scientific and technical achievements. Due to this, higher education institutions and their faculty are constantly searching for brand-new technologies, methods, and tools to train their students. English teachers are always at the forefront of utilising innovative information technologies since these technologies can effectively provide multimodal learning inside and outside the English language classroom. Artificial Intelligence is quickly becoming one of those advances whose appearance can profoundly change the teaching experience and make learning more personal. But until it proves its reliability in providing the appropriate education quality and developing students' subject matter and key competencies for lifelong learning, scientific interest will continue to grow, and heated debates will rage on. The problem of using AI tools for personalising learning in the English Language classroom must be approached comprehensively, taking into account the views of researchers, stakeholders, policymakers, as well as university teachers and students. Thus, this research aims to determine computer science undergraduate students' perceptions of using AI tools for personalising learning in the English Language classroom. To reach the aim, researchers developed a paper-based questionnaire that contained close-ended questions and statements for a rating on a 5-point Likert scale (5 – “strongly agree,” 4 – “agree,” 3 – “neither agree nor disagree,” 2 – “disagree,” 1 – “strongly disagree”). To select participants, the researchers used a purposive sampling method. As a result, the research population comprised 136 computer science undergraduate students from Kyiv National University of Technologies and Design (Kyiv, Ukraine) and Kyiv National Economic University named after Vadym Hetman (Kyiv, Ukraine). The survey was carried out in September-October 2024. The obtained data were analysed using frequency and mean percentage to interpret respondents' responses. The results showed that computer

science undergraduate students unanimously believe that AI tools are highly effective at helping personalise learning in the English language classroom.

Keywords—Artificial Intelligence, AI tools, Computer Science Undergraduate Students, English classroom, Higher Education Institutions, Personalised Learning, Teaching and Learning English.

I. INTRODUCTION

The advent of new technologies and their implementing in different spheres of human life always raise some concerns. And as history shows it takes a long time to ease these concerns which at first do not seem to be easy explainable. The emergence of Artificial Intelligence (hereinafter referred to as AI) and its accessibility to general public has the same fate. What we are witnessing now is a certain distrust of AI by researchers and practitioners and a rise of heated debates concerning their usage in educating students of different ages in our digital society today. And we do believe that these debates will continue until AI proves its reliability in developing students' subject matter and key competencies for lifelong learning and becomes a familiar part of our life.

Literature analysis shows that many scientists still believe that more research has to be done to better understand the full potential of AI and how it can affect the quality of education for present-day and future students, despite the fact that integrating AI tools into the educational process of higher education institutions is becoming more and more widespread. What we see is that different ideas have their strong supporters and strong opponents. And while there is still a debate over the decision to incorporate or not to incorporate AI into classroom teaching, both

Online ISSN 2256-070X

<https://doi.org/10.17770/etr2025vol3.8536>

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teachers and students learn actively to take advantage of the benefits AI provides.

Bates et al. believe that although higher education institutions can use AI for conducting various administrative tasks, it is too early to state that it can effectively improve learning outcomes [1].

On the contrary, Zhou, Zhang & Chan consider that education institutions should be aimed at adopting a more open approach to integrating and managing AI tools in educational process [2]. This approach is of paramount importance to both students and university teachers as it enables to enhance their AI literacy. The researchers also claim that the use of AI tools supports students' personal learning needs, enhances the principles of self-directed learning and positively influences students' productivity. On the other hand, the researchers admit the fact of ambivalent attitude of university lecturers to the use of AI tools in the education process. Thus, while some university lecturers openly and anticipatorily promote the use of AI in their classrooms, others try to impede this process and view it as a kind of academic misconduct.

The study conducted by Mallillin shows that the ability of AI to provide all the necessary information that students need in the learning process, to guide students' learning activities and to personalise learning helps improve their motivation towards study habits, attitude towards learning and boosts their academic performance [3]. The researcher is convinced that using AI in the learning process teaches students to express their ideas freely and to exercises their critical thinking.

Iqbal is confident that the application of AI tools in training students enables to meet their individual differences and creates favourable conditions for abandoning the one-size-fits-all approach [4].

Chan & Hu claim that present-day students believe that AI tools are effective in personalising learning support, assisting in writing and brainstorming, and conducting research and analysis [5]. However, they emphasise that implementing generative AI into the educational process can help address present-day students' needs and concerns only if educators and policymakers understand students' perceptions. The researchers explain that the insight into how students perceive AI enables policymakers to create guidelines and strategies for their responsible and effective implementation.

The research carried out by Shin also shows the application of Artificial Intelligence in the English language classroom using Flipped Learning has a positive impact on students' self-efficacy and helps improve students' listening and speaking skills [6]. In researcher's opinion, AI provides many advantages to university teachers since AI tools offer great opportunities for developing a wide range of classroom activities and contribute to their professional development.

Zhang, Sun, & Deng express a similar idea and state that introducing innovative digital technologies including

AI and smart classroom technologies into the English language teaching and learning contributes to the motivation for learning and cognitive activity and to the development of students' English language proficiency [7]. Applying a wide range of artificial intelligence and smart classroom technologies in the English language classroom helps university teachers personalise learning and create a more engaging learning environment for their students.

A similar idea can be found in Hartono et al. [8]. Researchers who investigate teachers' and students' perceptions and experiences on the application of AI tools in English language teaching come to the conclusion that present-day English teachers have a large arsenal of AI tools which have to be used in the English language classrooms, namely, intelligent tutoring systems, speech recognition and pronunciation practice tools, language learning apps and platforms, language assessment and evaluation tools, NPL-based chatbots etc. Their systematic use in the English language classrooms effectively improves students' language skills and helps provide personalised instruction.

Crompton et al. suggest that AI is distinguished by great possibilities in English language teaching and learning in general and in improving students' speaking, writing, and reading skills in particular [9]. The study conducted by researchers enables them to state that since the rapid development of AI, there is an urgent need to prepare such English language teachers who know what AI is, what benefits it has, and how English language teachers should use AI benefits in their classrooms to help students master English successfully.

Thus, the literature analysis clearly demonstrates that many present-day researchers share similar ideas concerning the effectiveness of AI tools for personalising instruction in the English language classroom. The use of AI tools for developing assignments makes it possible to address students' needs, interests and, and what is more important, to activate their cognitive and intellectual activity. In the context of our research, we believe that personalised learning is "a teaching and learning approach focused on creating favourable learning conditions in the classroom with the aim to expand students' knowledge and develop soft skills necessary for achieving success in the personal and professional lives" [10, p. 425].

And taking into account the fact that higher education is always at the forefront of utilising innovative information technologies the current research is intended to throw some light on computer science undergraduate students' perceptions towards using AI tools for personalising learning in the English language classroom.

II. MATERIALS AND METHODS

Since the researchers were interested in finding out computer science undergraduate students' perceptions towards using AI tools for personalising learning in the English language classroom, the researchers used a purposive sampling method to select participants. Given the specific focus on computer science undergraduate

students who learn English at university and who crave to master their English language proficiency, the purposive sampling method allowed the researchers to select respondents who met the criteria for the study. We explain the choice of computer science students because they have a high level of technical proficiency compared with students of other specialties, have an active interest in learning with AI technologies, and are open to incorporating AI tools into their educational practices.

To reach the aim researchers developed a paper-based questionnaire on the basis of the analysis of the scientific literature. The developed paper-based questionnaire contained five close-ended questions and 10 statements for rating on a 5-point Likert scale (5 – “strongly agree,” 4 – “agree,” 3 – “neither agree nor disagree,” 2 – “disagree,” 1 – “strongly disagree”).

The close-ended questions were therefore:

Do you agree that when learning English in today's classroom, teachers should consider using AI tools and AI-based tasks?

Do you believe that the use of AI tools and AI-based tasks makes your English lessons more personalised?

Do you believe that the use of AI tools and AI-based tasks in the English language classroom helps you improve your English language proficiency?

Does the use of AI tools in the English language classroom helps improve your AI literacy?

Does the teachers' responsible use of AI tools for creating and sharing educational content and AI-based tasks set a strong example of academic integrity for their students?

The measurement of computer science undergraduate students' agreement ratings of the statements about the usefulness of integrating AI tools in the English Language Classroom is based on the 5-Likert scale intervals presented in Table 1.

TABLE 1 INTERVAL LEVEL OF 5-LIKERT SCALE

Mean Interval	Perspective
1.00–1.80	<i>Strongly disagree</i>
1.81–2.60	<i>Disagree</i>
2.61–3.40	<i>Neither Agree nor Disagree</i>
3.41–4.20	<i>Agree</i>
4.21–5.00	<i>Strongly agree</i>

Before the survey was launched, the researchers informed participants that participation in the survey was voluntary and anonymous and the questionnaire did not contain questions regarding personal information. But the participants answered questions concerning demographic information.

136 Ukrainian computer science undergraduate students from Kyiv National University of Technologies and Design (Kyiv, Ukraine) and Kyiv National Economic University named after Vadym Hetman (Kyiv, Ukraine) expressed a desire to take part in the survey. After giving a

consent, all participants were given paper-based questionnaires with statements for rating. The survey was conducted in September-October 2024.

Table 2 presents the demographic information about respondents.

TABLE 2 DEMOGRAPHIC INFORMATION ABOUT RESPONDENTS

Variable		Number (N)	Percentage (%)
Gender	Male	97	71.3
	Female	39	28.7
Year of Study	First Year	41	30.1
	Second Year	44	32.4
	Third Year	29	21.3
	Fourth Year	22	16.2

Source: own study (N=136)

To interpret respondents' responses the obtained data were analysed using frequency and mean percentage.

III. RESULTS AND DISCUSSION

The aim of the first question is to find out if respondents agree that when learning English in today's classroom, teachers should consider using AI tools and AI-based tasks. The results show that 136 respondents (100%) have a unanimous answer on this question.

The second question of interest to researchers is “*Do you believe that the use of AI tools and AI-based tasks makes your English lessons more personalised?*” The results obtained clearly demonstrate that 86 respondents (63.2%) believe that the use of AI tools and AI-based tasks makes their English lessons more personalised. The responses given by 20 respondents (14.7%) are negative and 30 respondents (22.1%) find it difficult to answer this question. Fig. 1 visualises the results on question 2.

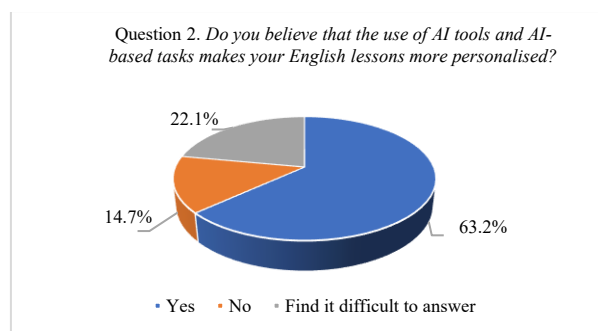


Fig. 1. Respondents' responses concerning the second open-ended question.

The third question was aimed at finding out if respondents believe that the use of AI tools and AI-based tasks in the English language classroom helps them improve their English language proficiency. The responses given by 92 respondents (67.6%) are positive. 16 respondents (11.8%) have an opposite opinion and 28 respondents (20.6%) find it difficult to answer the question. Fig. 2 demonstrates the results obtained on question 3.

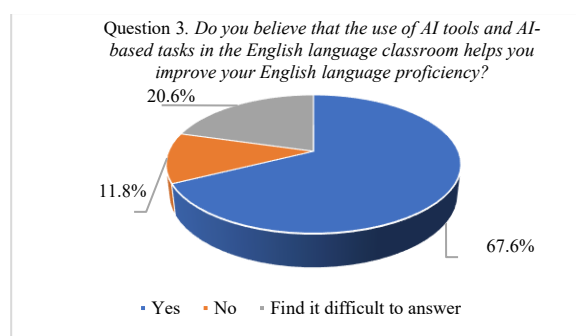


Fig. 2. Respondents' responses to question 3.

The fourth question aimed to find out if the use of AI tools in the English language classroom helped respondents improve their AI literacy. Thus, 84 computer science undergraduate students (61.8%) responded positively, and 33 computer science undergraduate students (24.3%) gave a negative answer. According to the obtained results 19 computer science undergraduate students (13.9%) found it difficult to answer this question. The aggregate results for question 4 are given in Fig. 3.

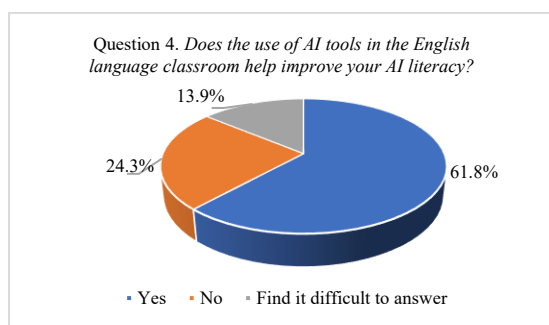


Fig. 3. Respondents' responses to question 4.

The purpose of question 5 was to determine whether the teachers' responsible use of AI tools for creating and sharing educational content and AI-based tasks set a strong example of academic integrity for the respondents. While 81 computer science undergraduate students (59.6%) gave a positive answer, 23 computer science undergraduate students (16.9%) responded negatively. 32 computer science undergraduate students (23.5%) found it difficult to answer the question. Fig. 4 presents the results obtained from question 5.

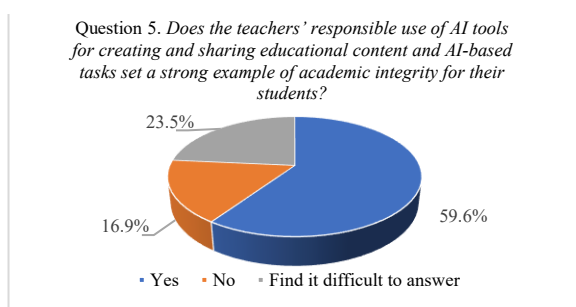


Fig. 4. Respondents' responses to question 5.

Table 2 presents the obtained results concerning computer science undergraduate students' agreement ratings with statements about the usefulness of integrating AI tools in the English Language classroom. For convenience, we use the abbreviation for response options in Table 2: SD (1) – strongly disagree, D (2) – disagree, N (3) – neither agree nor disagree, A (4) – agree, SA (5) – strongly agree.

TABLE 2 RESPONDENTS' PERCEPTIONS TOWARDS INTEGRATING AI TOOLS IN THE ENGLISH LANGUAGE CLASSROOM

Activities	Variables				
	SD (1)	D (2)	N (3)	A (4)	SA (5)
The use of AI tools helps personalise instruction according to students' English language proficiency	0	0	0	60	76
The use of AI tools helps personalise instruction inside the English language classroom according to students' interests	0	0	14	57	65
The combination of AI tools and traditional English language teaching methods helps personalise instruction in the English language classroom	0	0	11	52	73
The ability to use AI tools inside and outside the English language classroom makes the process of learning English more accessible and flexible	0	0	0	57	79
The use of AI translation tools helps me quickly find translations of unknown words, idioms or phrases	0	0	0	37	99
The use of AI translation tools for translating texts on various topics while doing homework assignments in English enables me to make sure that I understand their essence correctly	0	0	9	35	92
The use of AI tools helps me quickly find information I need to do my English homework assignments	0	0	17	58	61
The use of AI tools helps correct and improve my English pronunciation	0	0	19	51	66
The use of AI tools helps me check and correct my mistakes in writing essays	0	0	0	41	95
The use of AI-based tasks in the English language classroom makes lessons more interactive, enjoyable and up-to-date	0	0	0	52	84

Source: own study (N=136)

The obtained results show that the computer science undergraduates demonstrate strong agreement with the following statements, namely, the use of AI tools helps university teachers personalise instruction according to their English language proficiency ($\bar{x}=4.56$), the use of AI tools helps university teachers personalise instruction in the

English language classroom according to their interests ($\bar{x}=4.38$), the combination of AI tools and traditional English language teaching methods helps personalise instruction in the English language classroom ($\bar{x}=4.46$), the use of AI tools inside and outside the English language classroom makes the process of learning English more accessible and flexible ($\bar{x}=4.58$), the use of AI translation tools helps me quickly find translations of unknown words, idioms or phrases ($\bar{x}=4.73$), the use of AI translation tools for translating texts on various topics while doing homework assignments in English enables me to make sure that I understand their essence correctly ($\bar{x}=4.61$), the use of AI tools helps me quickly find information I need to do my English homework assignments ($\bar{x}=4.32$), the use of AI tools helps correct and improve my English pronunciation ($\bar{x}=4.35$), the use of AI tools helps me check and correct my mistakes in writing essays ($\bar{x}=4.69$), the use of AI-based tasks in the English language classroom makes lessons more interactive, enjoyable and up-to-date ($\bar{x}=4.62$).

IV. CONCLUSIONS

The current research was intended to throw some light on computer science undergraduate students' perceptions towards using AI tools for personalising learning in the English language classroom. The results demonstrated that the respondents perceived AI tools used in their English language classrooms as effective in improving their English language proficiency (reading, writing, speaking, listening skills, and pronunciation). Moreover, their usage allows them to consider their learning styles, needs, and interests. These respondents also believe that implementing AI-based tasks in the English language classroom can make lessons more interactive, enjoyable, and up-to-date, and they can get valuable hands-on experience working with various AI tools. In this context, we may assume that the purposeful use of AI tools and AI-based tasks can help university teachers personalise learning. For those respondents who expressed an opposite idea or found it difficult to answer the close-ended questions, we may assume that it might be connected with the fear of losing the possibility to freely communicate with groupmates or doing activities that require effort and thorough knowledge of the course material. The results also show that respondents agree that AI tools are efficient in checking and correcting mistakes in writing essays, improving their pronunciation, and helping them find information for doing homework. For those interested in mastering their English, AI tools help respond to their personal needs. According to the results obtained, most respondents believe that using AI tools in the English language classroom helps improve their AI literacy, and the teachers' responsible use of AI tools for creating and sharing educational content and AI-based tasks sets a strong example of academic integrity for them. To sum up, we can state that most respondents recognise the potential of AI tools in personalising learning in the

English language classroom and in helping them understand what they have to improve in primary English.

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Developing Computer Science Undergraduate Students' Communicative and Self-Expression Skills: Digital vs. Traditional Storytelling Methods

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Abstract—To succeed in the modern digital workplace, to express ideas clearly and effectively, and to be convincing, university graduates should be equipped with communicative and self-expression skills even if their future jobs do not involve constant communication with different people. Digital and traditional storytelling used in the English language classroom are considered efficient methods for developing these skills among computer science undergraduate students. With the appearance of Artificial Intelligence and free access to various AI tools, creating digital stories is becoming easier and easier, and today's students, being representatives of the digital era, are proficient with these tools. The research aims to examine computer science undergraduate students' perceptions of the effectiveness of digital vs. traditional storytelling methods in developing their communicative and self-expression skills. Using the designed paper-based questionnaire, the researchers collected data from 119 first- and second-year computer science undergraduate students. The data were collected during September-October 2024 and the obtained data were processed qualitatively. Results suggest that in today's English language classroom digital storytelling is a more convenient way of engaging students in expressing their ideas and personal points of view. Presenting their digital stories in front of the class and defending their views provide developing their communicative and self-expression skills. Concerning computer science undergraduate students who prefer writing stories, we can claim that they understand the value of such assignments since they help them gather their thoughts and express them more logically and structured.

Keywords—Communicative skills; Computer Science Undergraduate Students; Digital and Traditional Storytelling

Methods; English Language Classroom, Self-Expression Skills.

I. INTRODUCTION

Many modern scientists are convinced that the appearance of digital technologies and their implementation into the educational process of universities enable teachers to use innovative teaching and learning methods that inspire students' desire to acquire new knowledge and skills [1; 2]. Moreover, they claim that digital technologies modify conventional instruction so that it considers students' learning styles and becomes more autonomous, engaging, and personalised [3; 4].

What we believe is that although traditional teaching and learning methods and techniques used in the English language classroom aim to equip students with key language skills (reading, writing, speaking, and listening), innovative teaching and learning methods based on digital technologies open more opportunities for both teachers and students, make instruction more interactive and improve students' soft skills. The advantages of digital technologies include numerous opportunities to engage students in independent cognitive activity, the interactive nature of online educational content, the opportunity to share information among all participants of the educational process, and to get feedback etc. One more advantage of implementing digital technologies into the instruction of higher education institutions is that it can embrace various learning models (face-to-face, online, social, personalised, and hybrid) and enhance students' digital skills [5].

Online ISSN 2256-070X

<https://doi.org/10.17770/etr2025vol3.8559>

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Thus, Noytim believes that Web blogging, regarded as an innovative storytelling method, encourages students to self-express and enhance their reading and writing skills in English classes [6]. To support this point of view, the researcher explains that “Weblogs offer real communication in which writing and reading take place in an authentic environment and there is a real audience” [6, p. 1128]. In addition, the researcher states that collecting and analysing information for posts implies the development of students' analytical and critical thinking skills.

Research conducted by Malykhin et al. shows that such story-based teaching and learning methods and techniques as making up stories, expanding sentences, chain story writing, cutting down sentences, and writing storms used in English language classrooms help effectively develop Computer Engineering and Information Technology undergraduates' innovative thinking [7]. The researchers also determine sub-skills that constitute the basis of innovative thinking, namely, creativity, ability to analyse information, ability to think critically, ability to see the differences, openness to new experience, willingness to experiment, ability to summarise information, ability to group different ideas, ability to evaluate information critically, ability to find the way out of the situation, adaptability to change and ability to be agile.

To encourage students to improve their four language skills inside and outside the English language classrooms, and to develop their cognitive, communicative, and social skills, English language teachers should implement collaborative language learning. Mansor et al. claim that collaborative language learning implies the use of dialogue journal writing, which is an effective means for teaching students to express their thoughts and feelings in a foreign language, to develop their writing skills, and to improve their social skills [8].

Considering English as a global language, which opens wide opportunities for people worldwide, Arroba & Acosta find it helpful to apply innovative communicative strategies inside and outside the English language classroom [9]. Although researchers regard all four language skills as equally important, much effort should be put into developing undergraduate students' speaking skills. They explain that the ability to speak English fluently clearly indicates students' language proficiency and is connected with their communicative skills. In today's English language classroom, the development of speaking skills is impossible without the use of various speaking activities. However, if these activities are not student-centred, and ignore students' interests, needs, and previous experience of using English, engaging students in communication is a real challenge for teachers. In this connection, digital storytelling is effective in motivating students to develop their speaking skills.

To succeed in the modern digital workplace, to express ideas clearly and effectively, and to be convincing, university graduates should be equipped with communicative and self-expression skills even if their

future jobs do not involve constant communication with different people. In this regard, storytelling methods and techniques used in the English language classroom seem effective in enhancing these skills among students of different specialties.

A. Traditional Storytelling

Some researchers believe that storytelling performs not one but several functions in the classroom. Depending on the topic discussed, storytelling can enhance intercultural understanding and communication by teaching students to appreciate different perspectives on the problem or cultural traditions. It helps develop students' soft skills, namely, imagination and creative thinking skills and helps increase their verbal and written proficiency. In this regard, the following definition by Dvalidze is of scientific interest to our study: “Storytelling is a unique way for students to develop an understanding, respect and appreciation for other cultures, and can promote a positive attitude to people from different lands, races and religions” [10, p. 208].

Fachraini expresses a similar idea and claims that as one of the widespread techniques used in the English language classroom storytelling is distinguished by cultural value [11]. It also helps students master their listening and reading skills and significantly improve their grammar and pronunciation skills.

As one of the oldest forms of human communication, Lucarevschi believes storytelling plays a pivotal role in promoting education and cultural values [12]. The researcher states that the role of storytelling in facilitating comprehension is undeniable. While preparing a story, foreign language learners can visualise its content and use verbal repetitions, which makes it possible to create a highly contextualised story.

B. Digital Storytelling

Digital technologies have already changed the traditional way of delivering instruction in the English language classroom, the teaching and learning strategies used, the roles teachers and students play, and approaches to developing students' skills.

According to Zuana, classroom digital storytelling in the English language classroom is a means that combines “both personal narratives with the use of technology” [13, p. 28]. The study conducted by this researcher shows that digital storytelling helps students believe in their ability to speak English since it enables them to practice their English language speaking skills. In addition, students admit that preparing digital storytelling videos is challenging and requires much effort.

Arroba & Acosta maintain that applying authentic digital storytelling in the English language classroom enables undergraduate students to improve their vocabulary, grammar, and pronunciation, become aware of their weaknesses, and overcome speaking mistakes [14].

Gregori-Signes claims that along with language skills, digital story creating involves shaping a wide range of skills, namely, “research and writing skills, organization

skills, technology skills, presentation skills, interpersonal skills, or problem-solving skills, which, in turn, develop digital literacy, global literacy, technology literacy, visual literacy, or information literacy” [15, p. 45]. As an innovative teaching and learning tool digital storytelling helps teachers bring innovation into the English language classrooms, and raise the motivation and cognitive interest among their students that way. With regard to students, new approaches to selecting the content and images, its structuring, and the style of presenting prepared digital stories, provide students with more possibilities to manifest their creativity and flexible thinking skills, that is, to self-express.

In our research, we share the opinion expressed by Towndrow that digital story making and storytelling are the basis for developing agency in students, and the way they present their digital stories reveals “who we are as people, what we value, and what we would like others to notice about us” [16, p. 84]. The way of telling a digital story manifests students’ self-representation and self-expression skills and how they view and represent the content they create.

Syam concludes that digital storytelling inspires students’ curiosity and can turn them into interested readers [17]. Implementing digital storytelling into the educational process implies developing students’ writing and reading skills and ensures the improvement of their communicative skills.

Thus, the analysis of the relevant literature shows that storytelling methods and techniques used in the English language classroom may help improve students’ language skills and teach students to express their ideas freely, respect their groupmates’ opinions, reduce the risks of misunderstanding, help expand their horizons and networking opportunities. Therefore, the research aim is to examine computer science undergraduate students’ perceptions of the effectiveness of digital vs. traditional storytelling methods targeted at developing their communicative and self-expression skills.

II. MATERIALS AND METHODS

The participants in this study were 119 first- and second-year computer science students who studied English as a second language at Kyiv National University of Technologies and Design (Kyiv, Ukraine) and Kyiv National Economic University named after Vadym Hetman (Kyiv, Ukraine).

The discipline “English as a Second Language” taught to first- and second-year computer science students in the mentioned higher education institutions in Ukraine aims to develop language skills (reading, writing, speaking, and listening) and key competencies for lifelong learning, including communicative and self-expression skills. This discipline is a preparatory stage before students start specialising in developing their communicative competence in the IT sphere. Digital storytelling and writing essays are typical activities used in the English language classroom. While studying a definite topic,

English language teachers usually offer students tasks to create a digital story or to write an essay to show how well they absorb the educational material they learn and to present it in front of the class. Such a practice helps teachers understand how well the students have learned the lexical and grammatical material related to the topic. Moreover, these activities help students with different memory types develop their communicative and self-expression skills. To reach the research aim, which was to examine computer science undergraduate students’ perceptions of the effectiveness of digital and traditional storytelling methods targeted at developing their communicative and self-expression skills, the researchers developed a paper-based questionnaire which contained the following questions:

Do you find storytelling helpful in developing your communicative and self-expression skills? Explain why.

Which helps you express yourself better: creating a digital story or writing a story (an essay)? Explain your point of view.

What do you find most comfortable to present in front of the class: a digital story or a story created in written form? Explain your point of view.

During the data collection period, respondents were asked to carefully ponder the questions given in the questionnaire, and share their thoughts on developing their communicative and self-expression skills in the English language classroom via digital and traditional storytelling methods. The data were collected from September to October 2024, and the obtained data were processed qualitatively.

III. RESULTS AND DISCUSSION

The first question was aimed at figuring out if respondents found storytelling helpful in developing their communicative and self-expression skills. 76 respondents (63.9%) gave a positive response to this question. 25 respondents (21.0%) replied negatively and 18 respondents (15.1%) found it difficult to answer the question. Figure 1 shows the results of question 1.

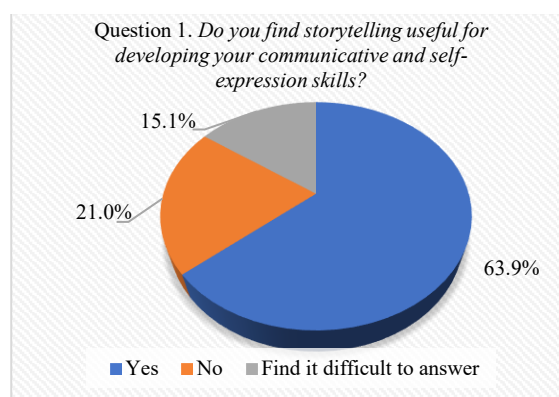


Fig. 1. Respondents’ responses to question 1.

76 respondents (63.9%) who admit that storytelling is helpful in developing their communicative and self-expression skills explain that this activity helps them better

understand themselves, learn to express their thoughts logically, and substantiate these thoughts with some facts or real-life examples. While preparing a story, they improve their vocabulary, which they can use in the future. These respondents claim that storytelling is an effective way of expressing their views on different topics. 25 respondents (21.0%) who neglect the usefulness of storytelling for developing their communicative and self-expression skills mention that the connection between these skills and storytelling is rather vague. In their replies respondents point out that they associate storytelling assignments only with requirements given in the syllabus of the discipline "English as a Foreign Language" and do not regard them as assignments for self-expression or communication with their groupmates. Concerning the 18 respondents (15.1%) who find it difficult to answer this question, we can assume that they lack self-reflection skills and are not used to analysing their emotions connected with such assignments.

The second question aims to understand respondents' opinions on which helps them self-express better: creating a digital story or writing a story (an essay). The results demonstrate that 68 respondents (57.1%) find it easier to create a digital story to self-express, while 31 respondents (26.1%) prefer writing a story. In addition, 20 (16.8%) respondents find it difficult to answer this question. Below are excerpts of responses in which respondents express their positions on using digital storytelling for developing their communicative and self-expression skills:

R10: *My level of English allows me not to write anything before I create a digital story. I can make some notes, which include information about the structure of a digital story and some reminders about images or ideas about the final product. That's all. ... Writing a story takes much time and does not allow to provide any visual support. Digital storytelling is an entirely different thing. It is an unusual way of expressing your personality and your thoughts. Putting your heart and soul in creating a digital story, can make your groupmates think about the same thing or the same situation in a totally different way.*

R25: *Although I like both activities, digital storytelling is more effective in developing my communicative and self-expression skills. The explanation is simple: before creating a digital story, I always write a text. It helps me stay focused and think through all the details. So, I can say that I always combine these two activities when I prepare a digital story. They are equally important in developing the mentioned skills, and the only difference between them is the way we present the results.*

R17: *I like writing stories because every story is unique. First, it allows me to express my ideas and my emotions freely and to understand my personal attitude towards the topic I write about. On the one hand, it is more challenging to write a story but on the other hand, a written story can offer any topic in depth which cannot be done with a digital story. Digital storytelling is an entirely different thing. It is more about presenting your ideas through visual and sound effects.*

R34: *I find it difficult to answer this question because before creating a digital story, I usually write an essay. I thoroughly choose vocabulary and phrases that relate to the topic of my essay and select images that visualise all the ideas described in the essay. I like English and the activities we do in our classes, but my English proficiency is not very high and I am afraid to make mistakes. Presenting a story makes me feel more confident. In my personal opinion, digital storytelling is inextricably linked with writing stories. The only difference is the way we present the results. Therefore, it is hard for me to decide which one helps me self-express better.*

The results demonstrate that digital technologies have already become integral to our everyday lives. It is evident that with the appearance of Artificial Intelligence and free access to various AI tools, creating digital stories is becoming easier and easier, and today's students, being representatives of the digital era, are proficient with these tools. The 68 respondents (57.1%) who opt for digital storytelling insist that access to various digital tools makes it easy to create digital stories that are optimal for visual perception. Among the main advantages of creating digital stories, these respondents mention the ability to choose any visual material they need, the content and structure of the presentation, to add music, or to convert text into sound. Moreover, a digital story usually requires less text, which respondents also find convenient. In their explanations, these respondents point out that such digital tools as Canva, Book Creator, Powtoon, PowerPoint, and SlidesGo are simple to use and are helpful in developing their creative thinking skills. As for those who prefer writing stories, we may assume that they understand the value of such assignments for developing their reasoning and persuasion skills. They also claim that writing a story helps them gather their thoughts and express them in a more logical and structured way. The results of question 2 are presented in Fig. 2.

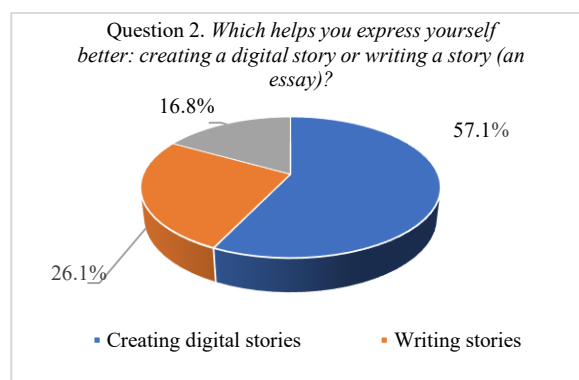


Fig. 2. Respondents' responses to question 2.

Question three seeks to answer to the following question: "What do you find most comfortable to present in front of the class: a digital story or a story created in written form?" According to the results obtained, 79 respondents (66.4%) find most comfortable to present a digital story in front of the class. In their replies, they explain that since a digital story is distinguished by more

vivid visual perception, presenting a digital story in front of the class seems to be a more modern way of self-expressing and showing creativity. We believe that despite the differences in presenting stories, both digital storytelling and traditional storytelling enable students to improve their presentation and communicative skills. However, as we can see, digital storytelling may provide reliable visual support and a more convenient way of presenting prepared educational content. 24 respondents (20.2%) do not mind presenting a story created in the written form. 16 respondents (13.4%) find it difficult to answer the question. Figure 3 provides the results of question 3.

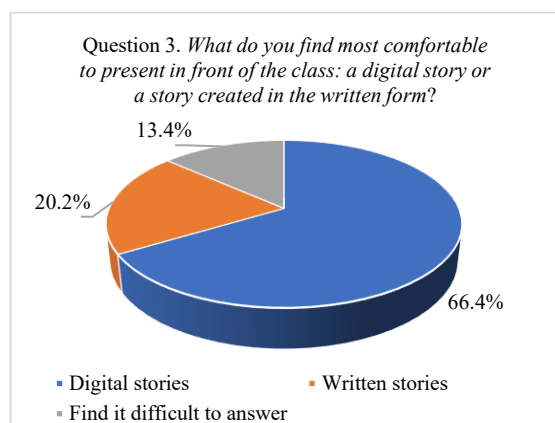


Fig. 3. Respondents' responses to question 3.

IV. CONCLUSIONS

The research examined computer science undergraduate students' perceptions of the effectiveness of digital vs. traditional storytelling methods targeted in developing their communicative and self-expression skills. The article also presented the practical experience of applying digital and conventional storytelling methods in the English language classroom. The research results demonstrate that most computer science undergraduate students consider digital storytelling more effective in developing their communicative and self-expression skills than writing a story. The advantages of digital storytelling include the ability to choose any visual material students need, the content and structure of the presentation, the ability to add music, or to convert text into sound. Moreover, free access to such digital tools as Canva, Book Creator, Powtoon, PowerPoint, and SlidesGo makes digital storytelling simple and user-friendly. In today's English language classroom, digital storytelling is a more convenient way of engaging students in expressing their ideas and personal points of view. Presenting their digital stories in front of the class and defending their views provide developing their communicative and self-expression skills. Concerning computer science undergraduate students who prefer writing stories, we can claim that they understand the value of such assignments since they help them gather their thoughts and express them in more logically and structured.

Although the research demonstrates the active use of digital tools in higher education by both students and university teachers, more research is needed to validate the effectiveness of digital storytelling in developing students' communicative and self-expression skills. Future research will consider a broader sample, including students of other specialties, and a longitudinal perspective that enables the recognition of any positive or negative changes in students' attitudes toward the use of digital storytelling.

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Creating a Professional Development Program to Enhance General Education Teachers' Skills in Applying Digital Learning Platforms for Teaching and Learning

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Abstract—This study aims to develop a comprehensive professional development program to help general education teachers integrate digital learning platforms into the teaching and learning process using the ADDIE instructional design model. The program is structured around the five key phases of the ADDIE model - Analysis, Design, Development, Implementation, and Evaluation - providing a systematic framework for effective digital platform integration. The training program focuses on equipping teachers with the necessary skills to select, implement, and evaluate digital tools in various instructional contexts. The program development process considers best practices in instructional design and technology-enhanced learning while addressing teachers' pedagogical needs. Special emphasis is placed on fostering engagement, adaptability, and practical application of digital resources in blended and online learning environments. By aligning professional development with the ADDIE model, this study provides a structured approach to supporting teachers in effectively utilizing digital platforms for instructional purposes. Future research will focus on piloting the program and assessing its impact on teachers' digital competencies and classroom practices.

Keywords— *Digital learning platforms, instructional design, ADDIE model, teacher professional development, technology integration in education.*

I. INTRODUCTION

In the 21st century, digital learning platforms have become an integral part of modern education, offering new possibilities for student-centred, collaborative, and knowledge-building learning approaches [1], [2], [3]. These platforms support deeper learning by providing features such as learning process management, integrated content creation, communication scaffolding, community-building tools, and learning analytics [4], [5]. When effectively implemented, they enhance teaching and learning practices, making education more interactive, engaging, and adaptable to individual student needs [3].

Digital learning platforms come in various forms, including e-learning systems, learning management systems (LMS), virtual learning environments (VLE), specialized educational tools, and mobile applications designed to enhance learning [6], [7], [3]. As advancements in educational technology (EdTech) continue to evolve,

Online ISSN 2256-070X

<https://doi.org/10.17770/etr2025vol3.8521>

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strategic European policies such as the Digital Education Action Plan (2021–2027) and the Policies for the Digital Transformation of School Education (2023) emphasize the need for innovative, research-based technologies that add pedagogical value to the teaching and learning process [3], [2]. Our research primarily focuses on the most advanced digital learning solutions, which we categorize as Learning Experience Platforms (LXP) such as Eduten Playground, LearnLab and similar technologies [6]. These platforms as well as other LXP based educational technologies create a foundation for innovative pedagogical strategies rooted in constructivist learning theories.

Since 2019, our research team has actively collaborated with schools and educators to implement digital learning platforms in practice, leveraging insights from the DIMA_LT project (<https://di-ma.lt>). The integration of Learning Experience Platforms (LXP) has been a key focus in our international research collaborations, including efforts between Germany and Lithuania [8]. As part of these initiatives, researchers have investigated the impact of Bettermarks (Germany) and Eduten Playground (Lithuania) - two LXP-based platforms designed for mathematics education on K-12 learning environments. Findings from case studies [8] in German and Lithuanian schools suggest that LXP-based platforms offer significant pedagogical benefits, such as increasing student engagement, supporting differentiated instruction, and improving learning outcomes. Teachers reported that these platforms allowed them to monitor student progress more effectively and provide real-time formative feedback. However, challenges remain, including teacher training gaps, the need for structured instructional design models, and the integration of these platforms into existing curricula.

International research also indicates that, despite the potential benefits of digital learning platforms, educators face a range of challenges in their implementation, particularly when adopting constructivist methodologies [9], [3]. These challenges include: adapting to constructivist teaching approaches [10], [5]; implementing new pedagogical strategies [11]; creating and curating digital educational content [12], [2], [13]; designing and managing the learning process effectively [14], [15]; monitoring student progress, evaluating learning outcomes, and providing meaningful feedback [16], [15], [17]; facilitating and managing student collaboration in digital environments [18].

Therefore, in order to have these platforms successfully integrated into general education, teachers must possess the necessary skills to utilize them effectively [2], [3]. Higher education institutions, particularly those responsible for teacher training and professional development, play a vital role in preparing educators to navigate and implement technology-driven instruction. Consequently, these institutions are actively seeking effective models to equip teachers with the competencies required for modern educational environments [19], [20]. Professional development programs are essential in this regard, enabling

teachers to design, implement, and assess instructional strategies that incorporate digital tools effectively.

Instructional design models provide a structured approach to designing, developing, implementing, and evaluating technology-supported learning experiences. By applying these models, teachers can systematically enhance their ability to create engaging, pedagogically sound, and technology-integrated instructional strategies that meet the demands of modern education. The concept of instructional design supports learner-centered, technology-enhanced pedagogy, enabling teachers to make informed decisions about technology use and develop structured lesson plans that effectively integrate digital tools [19], [20]. Additionally, instructional design helps educators justify their choice of technology and create well-planned scenarios for implementing and managing effective lessons and learning activities [20]. Several instructional design models, such as TPACK [21], ADDIE [22], 4C/ID [23], CAFE [24], and ELED [25], are widely analyzed in the scientific literature and serve as foundational frameworks for developing professional development programs.

This study employs a theoretical and conceptual research approach to develop a professional training program designed to enhance general education teachers' competencies in integrating digital learning platforms. The study is structured around the ADDIE instructional design model, which serves as the foundational framework for program development. This model is widely recognized for its systematic and iterative nature, ensuring that training programs are effectively designed, implemented, and evaluated. The ADDIE model consists of five essential phases: Analysis, Design, Development, Implementation, and Evaluation. Each phase is systematically examined and contextualized to align with best practices in digital learning integration and teacher professional development. A systematic literature review on existing frameworks in teacher training and digital education was conducted to inform the program design. The primary sources used in this theoretical analysis include research on teacher training models and digital competency frameworks [21]; studies on instructional design and technology-enhanced learning (e.g., [24], empirical findings on the effectiveness of digital learning tools and platforms in K-12 education, and best practices in online and blended learning methodologies. The study utilized a structured review of peer-reviewed academic sources, books, and policy reports to ensure a comprehensive theoretical foundation. The literature review process involved systematic searches in databases such as APA PsycInfo, ERIC, JSTOR, Google Scholar, and ScienceDirect. The search terms included “digital learning platforms,” “teacher professional development,” “instructional technology,” “blended learning,” and “ADDIE model in education.” The selection criteria for sources included publications from 2005 onwards, ensuring relevance to modern educational technology practices, studies focusing on K-12 teacher training and digital pedagogy, and empirical and theoretical research articles that examine instructional design models in teacher education. Based on the synthesized literature and

theoretical models, a structured training program was conceptualized.

In line with this, the present article aims to present a comprehensive professional development program that helps general education teachers integrate digital learning platforms into the teaching-learning process. The program focuses on equipping teachers with the necessary skills to select, implement, and evaluate digital tools in various instructional contexts while addressing their pedagogical needs. Special emphasis is placed on engagement, adaptability, and the practical application of digital resources in blended and online learning environments. By aligning professional development with the ADDIE model, this program provides a structured approach to supporting teachers in effectively utilizing digital platforms for instructional purposes. The findings serve as a foundational guide for educators, policymakers, and instructional designers seeking to enhance digital competency among general education teachers. However, there are some limitations, as a theoretical study, this article does not include empirical testing or direct implementation of the training program. Moreover, future research should focus on piloting the program in educational settings and assessing its impact through qualitative and quantitative methodologies.

II. MATERIALS AND METHODS

This section of the article explores the development and implementation process of the professional development program for teachers, along with its content, based on the ADDIE model.

The ADDIE model is a widely used framework for instructional design and training development [26], [27]. It consists of five key phases: Analysis, Design, Development, Implementation, and Evaluation [28]. Originally developed in 1967 by Reiser and Mollanda, the model provides a structured and systematic approach to creating instructional materials and learning experiences. The primary goal of the ADDIE model is to facilitate the design of effective and efficient educational programs by structuring the development of teaching strategies, instructional methods, media, and learning materials [29], [30]. The process follows a sequential order, ensuring that each phase builds upon the previous one. However, a core feature of this model is its iterative nature, allowing for continuous feedback and improvement at each stage.

The Analysis phase serves as the foundation of the instructional design process, focusing on determining what learners need to learn. This involves conducting a needs assessment, identifying learning gaps and challenges, and performing a task analysis to define the necessary skills and knowledge required for the learning process. At this stage, the key outcomes include learner profiles, identification of specific learning needs, and an in-depth analysis of tasks based on these needs [31]. By systematically gathering and evaluating this information, instructional designers can ensure that the learning objectives align with the actual requirements of the target audience.

In the Analysis phase, teachers participating in the program learn how to assess the diversity and needs of their students to effectively implement digital learning platforms. This analysis is particularly important when integrating digital tools into teaching and learning, as research suggests that technology-enhanced learning environments can significantly increase student engagement and participation. By understanding their students' technological skills, learning preferences, and potential challenges, teachers can select and adapt digital learning platforms that best meet these needs.

Additionally, participants explore a variety of digital learning platforms and their capabilities. It is essential to align learning objectives with platform capabilities to ensure that the chosen digital tools effectively support instructional goals. Studies indicate that when using digital learning platforms, teachers should base their pedagogical decisions on students' prior experiences, motivation, and self-regulation abilities. This knowledge allows teachers to create personalized, engaging, and effective learning experiences, ultimately enhancing student outcomes while also developing their own competencies in utilizing digital tools for educational purposes.

Based on their assessment of learner diversity and needs, as well as an analysis of technological diversity, teachers progress to the next stage—instructional content design. The Design phase plays a fundamental role in the development of learning materials. During this stage, the structure and specifics of the materials are outlined, guided by the overall development and implementation process [32]. This phase requires meticulous planning and a thorough understanding of the educational goals to be achieved, along with strategies for designing materials that effectively meet these objectives. Key outputs of this phase include the syllabus and lesson plan, which serve as essential blueprints for crafting suitable teaching and learning materials.

Effective instructional content planning for teaching and learning with digital learning platforms involves four interconnected levels: course, module, lesson, and activity. At the course level, teachers learn to develop a comprehensive annual plan that aligns with national curriculum requirements, ensuring that both standard and self-developed materials meet educational guidelines. This stage also involves strategizing the integration of various learning formats - traditional, distance, blended, and hybrid - to create a flexible and cohesive learning experience. Moving to the module level, teachers learn how to divide courses into structured modules that are often organized on a weekly basis, with each module assigned a specific title and clearly defined learning objectives. This modular approach allows for efficient content delivery, student progress tracking, and optimized use of digital platforms for resource sharing and interaction. Within each module, the lesson level focuses on structuring learning content around specific topics. Teachers learn how to establish learning outcomes, determine the most effective delivery methods and allocate appropriate time for each lesson, ensuring seamless integration of digital platforms to

enhance instruction. Finally, at the activity level, teachers curate and organize learning materials such as textbook excerpts, digital resources, and interactive assignments. Step-by-step guidance is provided for project-based tasks and collaborative activities, with the careful selection of educational technologies like interactive quizzes, virtual labs, or shared documents to maximize student engagement. Maintaining a consistent structure in weekly instructional plans helps create a predictable learning environment, fostering effective study habits, increasing engagement, and leveraging the full potential of digital learning platforms.

The third stage, Development, involves transforming the instructional design into practical, functional learning activities. During this phase, the planned blueprint is brought to life by creating educational materials and resources. At this stage, digital learning platforms are integrated into the teaching and learning process, ensuring they align with the instructional goals and enhance the learning experience [33].

After completing the instructional content planning phase, teachers move on to designing engaging and purposeful learning activities that support students in achieving their learning objectives. These activities can take various forms, including collaborative projects, individual assignments, quizzes, discussions, problem-solving tasks, research initiatives, presentations, case studies, and role-playing exercises. The process of organizing these activities typically follows three stages: preparation, engagement, and reflection. During the preparation stage, teachers set clear expectations, prepare materials, and provide guidance on the task objectives and processes. This stage also involves learning how to familiarize students with any digital tools that will be used to ensure they feel confident in navigating the learning platform. The engagement stage focuses on active participation, where students collaborate and interact while teachers facilitate the process, offering support and ensuring that the chosen digital tools enhance the learning experience. The final stage, reflection and evaluation, involves encouraging students to reflect on their performance, analyze their learning, and receive constructive feedback. Teachers can use these insights to adjust future activities and improve the overall learning experience. When selecting or designing activities, teachers should consider their students' specific needs, including those with special educational requirements. If using online resources, activities should be adapted to fit the classroom context. Teachers can also test their instructions with a student to ensure clarity and accessibility. When introducing new educational technologies, such as Canvas or Google Classroom, it is essential to provide clear demonstrations and conduct pre-tests to confirm functionality and accessibility. Digital learning platforms offer diverse activity options, including reflective tasks like online discussions and summaries, productive activities such as content creation and project collaboration, synchronous interactions through live polls and webinars, and asynchronous activities like forum

discussions and independent tasks. By thoughtfully designing and implementing these activities, teachers can create more engaging, accessible, and effective learning experiences for their students.

The Implementation phase involves putting the developed learning system into practical use within the educational setting [34], [35]. This stage focuses on applying the instructional strategies, tools, and materials designed during earlier phases to facilitate actual learning experiences.

To ensure effective student engagement and active participation in instructional interactions, it is crucial to provide appropriate support and feedback, offer clear instructions, and carefully select educational technologies that facilitate communication and learning. Interaction between learners and learning content requires the use of accessible and well-structured materials in diverse formats. While this may seem straightforward, implementing it effectively in digital environments can be challenging. Students should be encouraged to explore learning materials in ways that suit their preferences, and whenever possible, teachers should offer multiple content formats to accommodate different learning needs, particularly for students with special educational requirements. In teacher-learner interaction, maintaining consistent communication through text, audio, and video messages is essential. Virtual communication tools should be leveraged to provide timely responses, ongoing support, and structured check-ins to track student progress, deliver feedback, and foster motivation. Using diverse communication strategies - such as one-on-one meetings, small group discussions, and whole-class interactions - can further enhance engagement. Additionally, incorporating a mix of text-based and multimedia messages helps strengthen social, cognitive, and emotional connections in the learning process. Peer interaction is equally important, and teachers should facilitate collaborative opportunities by forming learning groups and encouraging teamwork. Recognizing students' differences and assigning leadership roles can promote peer learning and support. Learner-content engagement should also serve as preparation for meaningful collaboration, ensuring that students review materials before engaging in discussions and group work. While peer interaction happens primarily among students, teachers should oversee the process, offering guidance and support when needed, as it closely aligns with teacher-learner engagement.

In general education, parental involvement plays a significant role in student success. Providing parents with guidance, practical tips, and resources can help them support their children's learning at home. Organizing training sessions or informational workshops can further equip parents with strategies to assist their children in working with digital learning platforms effectively. Choosing the right educational technologies is crucial in fostering successful collaboration and pedagogical interaction in digital learning. In this context, technology acts as a mediator that facilitates engagement across all interaction types. Teachers are encouraged to refer to educational technology classifications and carefully

evaluate which tools best align with instructional goals, learning content, and planned activities. Thoughtful selection and integration of these tools can significantly enhance the learning experience, improve engagement, and create a more effective and interactive digital learning environment.

The Evaluation phase in this learning process continues until the formative evaluation is completed, with the primary objective of identifying areas that require revisions and improvements [31], [36].

Assessing student performance in digital learning platforms can present various challenges, and teachers are encouraged to apply both summative and formative assessment strategies to achieve a comprehensive understanding of student progress. One effective approach is to use multiple data sources, going beyond traditional summative methods like tests and exams to consider formative indicators such as students' contributions to discussions, the frequency with which they lead group projects, share learning resources, or assist peers. Additionally, teachers should make use of the features offered by educational technologies, as many digital learning platforms automatically track performance data and provide learning analytics that can deliver valuable insights into student engagement and achievement. Peer assessment can also be a useful strategy, especially during collaborative projects, as it helps students develop a sense of accountability and learn from each other's strengths. Self-assessment strategies further support this process by encouraging learners to reflect on their progress and identify areas for improvement. Involving parents in the assessment process, particularly by seeking their feedback on their children's online learning activities at home, can also provide important context about a student's learning experience. Importantly, assessments should not only measure content mastery but also serve as tools to promote reflective thinking and independent learning skills. By encouraging students to evaluate their own performance, teachers help foster self-directed learning habits that are crucial for success in online and hybrid educational settings.

Figure 1. provides the overall structure of the developed program.

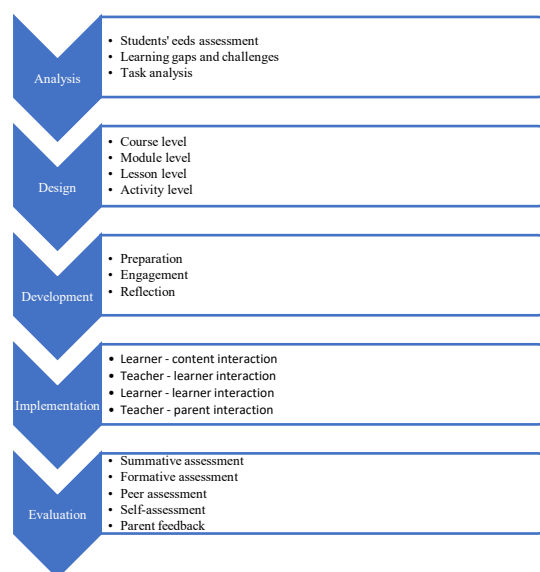


Fig. 1. The structure of the professional development program for teachers.

III.RESULTS AND DISCUSSION

This study highlights the importance of structured professional development programs in equipping teachers with the necessary skills to effectively integrate digital learning platforms into their teaching practices. By following the ADDIE instructional design model, the program developed provided a systematic approach to training teachers, ensuring that they could assess their students' needs, select appropriate digital tools, and implement engaging, technology-enhanced instructional strategies.

The piloting of the program involved 61 in-service teachers, with 37 participants from Lithuania and 24 from Germany. The participants were general education school teachers, who taught a variety of subjects, including mathematics, science, and English language studies, and worked with students ranging from primary education to gymnasium level.

The professional development program comprised 40 academic hours and was delivered through four separate training sessions via ZOOM platform held on different dates between March and May 2024. Each session lasted six academic hours. In addition to the online sessions, participants were assigned homework tasks and engaged in self-paced learning through the Moodle e-learning system, where they studied relevant topics asynchronously.

Before the training began, the researchers, who also served as trainers, provided a detailed explanation of the study procedures and obtained informed consent from all participants. They were assured that their identities would remain confidential, with names replaced by numerical identifiers during data analysis.

To evaluate the impact of the training, pre- and post-training self-assessment questionnaires were administered, measuring teachers' competencies in ADDIE-based

instructional skills within the context of digital learning platforms. Additionally, open-ended questionnaires were used to collect qualitative insights regarding teachers' expectations and perceptions of the training experience. Future research works will discuss data and findings on piloting the program and assessing its impact on teachers' digital competencies and classroom practices.

The pilot results in general revealed that participants greatly appreciated the structured nature of the training program. The thoughtful combination of live instruction and self-paced tasks effectively supported both skill acquisition and reflective learning. Teachers reported a noticeable improvement in their ability to assess learners' needs, design instruction grounded in the ADDIE model, and select digital tools that aligned with pedagogical goals. The program's emphasis on learner-centered pedagogy and technological adaptability further contributed to an increase in teachers' confidence and efficacy in integrating digital platforms into their teaching. Additionally, the implementation of strong ethical and confidentiality protocols fostered a sense of trust among participants and reinforced the integrity of the research process.

Moreover, the study reinforced the idea that effective technology integration in education requires more than just access to digital tools. It necessitates comprehensive teacher training that aligns with pedagogical goals and technological affordances. The confidentiality measures and ethical considerations ensured that participants felt comfortable engaging in the research, thereby strengthening the validity of the study's findings.

Future research should focus on evaluating the long-term impact of the program by assessing teachers' classroom practices, student engagement, and learning outcomes. Additionally, expanding the study to include a broader and more diverse group of educators could provide further insights into the scalability and adaptability of the ADDIE-based professional development model.

VI. CONCLUSIONS

This study confirms the relevance and applicability of the ADDIE instructional design model as a systematic and iterative framework for developing professional development programs aimed at enhancing teachers' digital competencies. Each phase of the model, namely Analysis, Design, Development, Implementation, and Evaluation, was effectively contextualized to address pedagogical needs in technology-enhanced learning environments. The model's structure ensured that professional development was grounded in evidence-based instructional strategies and could be adapted for diverse educational settings.

The study demonstrates that well-structured professional development programs, particularly those designed with the ADDIE model, can comprehensively address the pedagogical and technological challenges faced by teachers in integrating digital learning platforms. The program not only introduced educators to various digital tools but also enabled them to align these tools with specific instructional goals, student needs, and learning contexts. This alignment

is critical for promoting learner-centered teaching practices and personalized instruction in digital and hybrid environments.

The findings highlight the need for structured, evidence-based teacher training frameworks in response to growing digital transformation demands in education. The program serves as a replicable model for teacher education institutions and policy makers, especially in light of European digital education strategies. It demonstrates how instructional design models can bridge the gap between technological innovation and practical classroom application.

While the theoretical model and pilot implementation yielded promising results, the study acknowledges its limitations due to the lack of long-term, large-scale empirical evaluation. Future research should examine the sustained impact of the training on classroom practices, student engagement, and academic outcomes. Longitudinal and comparative studies could further validate the scalability and adaptability of the ADDIE-based professional development approach across different educational contexts and systems.

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Possibilities of Developing Creativity through the Study Subject of Geometric Modelling: Students' Point of View

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Abstract- The article is based on an interdisciplinary approach that incorporates research on education and a study subject. An interdisciplinary approach is extremely important in modern higher education when the same object is studied in the context of two or more subjects. It is also the field of engineering education that is currently highly relevant for universities with a technical profile. Lecturers of the subject should consider not only the content of the study subject but also the didactics of higher education and general competences, including creativity competence, which is perceived as a necessity in the workplace of the 21st century. Therefore, the aim of the article is to analyse the possibilities of creativity through the study subject of Geometric Modelling from the point of view of students. This study subject was chosen deliberately since students are learning to work with AutoCad and Blender software. Their goals are to create 3D models, model them, and visualise them. The article discusses the case of the study subject of Geometric Modelling delivered at VILNIUS TECH. Quantitative research was used, involving a survey of first-year students, which included 93 participants from the Multimedia and Computer Design study programme. To explore the competence of creativity, the areas of exploration, generation, creation, and evaluation were identified. Although most students believe that the study subject fosters creative thinking, they do not always perceive the analysed topics or assigned tasks as contributing to their creativity. They treat it more as the ability to learn how to work with the program and master its functions. It appears that this is influenced not only by the specifics of the study programme and the study subject, but also by the nature of first-year studies. The findings further highlight the importance of expanding the interdisciplinary approach in higher education institutions.

Keywords- competence of creativity, Geometric modeling, AutoCad, Blender, engineering education, didactics of higher education.

I. INTRODUCTION

In today's fast-paced technological context, creative thinking skills are becoming essential skills that enable students and graduates to adapt to new challenges and innovations in any sector of the labour market. The ability to find new solutions, to improve, develop, and visualise complex models encourages students to think outside the traditional box and to continuously search for new solutions. Creativity is gaining more and more attention as technology is penetrating into different areas of life and even changing some of the functions of human work. According to recent international surveys, creativity can be defined as "the competence to engage productively in the generation, evaluation and improvement of ideas, that can result in original and effective solutions, advances in knowledge and impactful expressions of imagination" [1].

Geometric modelling (GM) has become an interesting and important branch of engineering in recent decades. Its theories are mainly related to mathematics and computer science, and its applications are diverse: industrial design, computer graphics and animation, CAD/CAM, architecture, and others. Different programs are used in GM studies nowadays: Blender, Autodesk 3ds Max, Autodesk Maya, SketchUp, Zbrush and others. Depending on the field of study and the intended learning outcomes, universities decide on their choice individually. VILNIUS TECH currently uses Blender and Autodesk AutoCAD computer programs for GM in the study programme "Multimedia and Computer Aided Design". It is expected that by using these programs students will be able to create innovative, safe and aesthetically pleasing products that will meet the needs of the market today and promote sustainable technological development.

Geometric modelling is an essential component of multimedia and computer-aided design, as it allows the

Online ISSN 2256-070X

<https://doi.org/10.17770/etr2025vol3.8522>

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creation and manipulation of three-dimensional shapes and objects. One of the most important aspects is the creation of detailed and realistic objects that can be used in a wide range of applications, from animation to architecture. For example, the modelling of trees has been widely explored in computer graphics. Recent improvements in high-resolution sensors and data processing techniques make it possible to collect 3D datasets of real trees and create increasingly realistic branch structures [2]. A geometry-aware image compositing process has been developed to create new urban self-driving scenarios by augmenting existing images with dynamic objects from other scenes [3]. Realistic human head avatars are created from a single photo [4] using an RGB-D selfie camera [5], based on specific personal characteristics [6], and detailed 3D models of people are generated with different clothing and corresponding skin weights [7]. In game development, GM is used for creation of interactive environments and characters that react to player actions. A new method has been developed to rapidly simplify 3D geometric models in digital twin-based manufacturing systems, reducing the complexity of the model data, speeding up rendering and ensuring fast interaction of the digital twin with the physical manufacturing system, resulting in a low-latency visual effect [8].

II. MATERIALS AND METHODS

Data were collected through an analysis of the scientific literature and a quantitative research approach using written surveys. The survey targeted first-year Multimedia and Computer Design students at VILNIUS TECH and was conducted in May 2024. The 1st course consists of 3 groups of Lithuanian students and 1 international student. The questionnaires were distributed to 105 first-year students and 93 responses were received. Students study the GM study subject for one semester. The acquired knowledge and abilities are the basis for learning subjects in higher courses. Therefore, the research aims to analyse the possibilities of creativity from the students' perspective through the study subject of Geometric Modelling. In this course, it was decided to use only two programs: Blender and AutoCAD. Blender is focused on creative and artistic modeling and only surface objects are created in it. AutoCAD knowledge provides additional tools for technical and precise modeling when preparing objects for 3D printing. The main goal of GM is the ability to model precise three-dimensional objects using the aforementioned software. The study is longitudinal and continues in the higher course, where the focus is on the variety and complexity of tasks in order to develop students' creativity.

III. RESULTS AND DISCUSSION

Regarding the creativity fostered by the course of GM, the first thing analysed was the students' attitude towards whether the content and tasks of the study subject foster creativity (Fig. 1). The results show that as many as 75% of students confidently state that this subject encourages their creativity. This attitude is revealed and elaborated in the following questions. There were no respondents who

pointed out that the subject stimulates creativity little or not at all. This result directly reflects the focus of the course content and the tasks on the development of creativity in engineering studies.

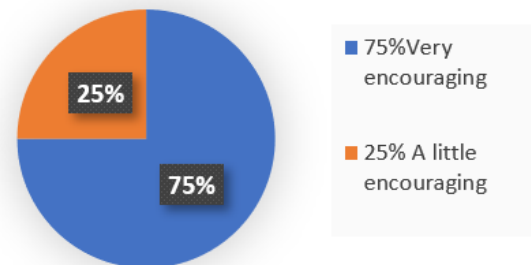


Fig. 1. Development of creativity in the study subject of Geometric Modelling.

Creativity competence is developed through four interrelated components, which can be flexibly applied in a variety of creativity-enhancing study methods or just used as steps in a task:

research (identifying problems and creative opportunities, gathering, connecting, and critically evaluating information necessary for creativity);

idea generation (conceiving and proposing ideas, selecting those significant for oneself and others, and considering them from various perspectives);

creation (acting ethically and independently, embracing risk and mistakes, using creative methods and tools flexibly, and refining, presenting, and sharing creative outcomes);

evaluation of creative ideas that are significant to oneself and others (assessing and reflecting on the novelty, value, and creative process of the product/solution).

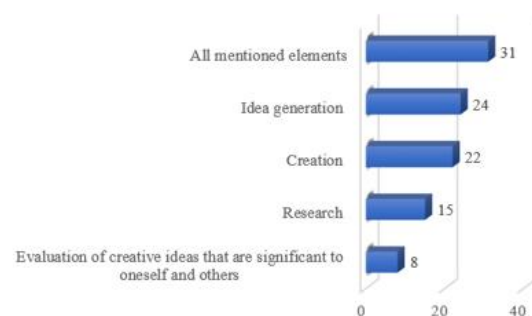


Fig. 2. Elements of creativity in the understanding of students.

It is important to identify the students' perception of the dimensions they attribute to creativity competence (Fig. 2) and the dimensions of creativity they apply in the GM subject (Fig. 3). An analysis of the answers shows that the results of both questions highly correlate with each other. The students' attitudes on two items are in full agreement. Firstly, as many as 31% of the students say that all the items identified belong to the creativity competence (Fig. 2) and that they all are applicable to the study subject of GM (Fig. 3.). Secondly, there is complete agreement (8%) on the last element of creativity, which concerns the evaluation of

creative ideas that are significant for oneself and others. This result is worth paying attention to and thinking about what could improve the results. The GM lecturer should point out that much more attention should be paid to the discussion and reflection on the completed tasks. The assessment part is important for creativity competence, as reflecting on one's own performance and evaluating the work of others encourages students to develop creativity competence by explaining the value of the task or solution to oneself and to others, making comparisons, and suggesting what could be done differently or improved. In this way, the result can acquire other forms or be related to interdisciplinary contexts.

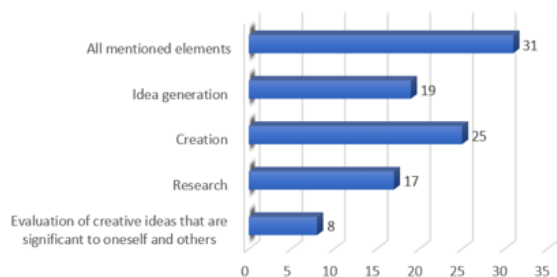


Fig. 3. Elements of creativity applied in the study subject of GM.

Another difference between the perception of creativity by the students (Fig. 2) and the application of creativity in the study subject of GM (Fig. 3) should be noted. A 5% difference can be seen when students assess the component of idea generation. This could be explained by the fact that students receive their tasks from a lecturer who has planned the study process and is working towards the set outcomes of the study subject. The variety or differentiation in the presentation of tasks could probably be considered. The lecturer could vary and, depending on the learning outcomes of the course, could allow/suggest that students come up with the idea of the task, work it out and achieve the result. Without the idea generation phase, students lose the opportunity to develop their creativity competence.

After clarifying students' attitudes and perceptions about the structure of creativity competence, it is important to know how students feel about each task they are given. Students were asked to rate 6 tasks on a scale from 1 (definitely not) to 5 (definitely yes).

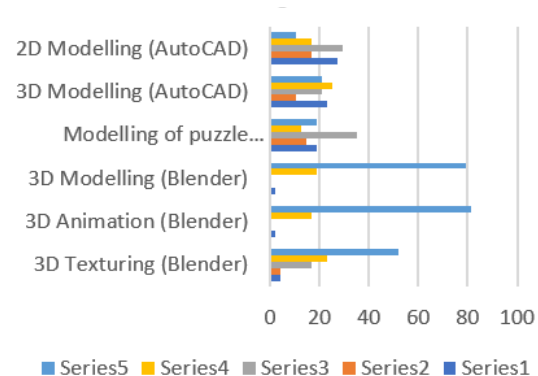


Fig. 4. Level of creativity of GM tasks (students' views) (rate from 1 (definitely not) to 5 (definitely yes).

The creativity of students is highly stimulated by GM, as confirmed by other researchers. In architecture and engineering, for example, geometric modelling enables the creation of accurate and detailed visualisations of buildings and other structures, which help to better understand and plan projects. Banfi [9] discusses how buildings have evolved from being physical objects to digital expressions, where not only their structure but also the information related to them is important. The interactive geo-information three-dimensional model developed by Ahmad et al [10] includes the creation of a digital terrain model and three-dimensional spatial object models, determines the quality of the provided cartographic material, and shapes the development methodology. It also allows for the efficient creation and editing of complex objects, saving time and resources, and the production of appropriate visualisations. For example, low-cost modelling techniques are essential and widely needed for heritage conservation, especially in poorer countries [11]. Xu et al. [12] proposes to create and visualise three-dimensional models using the 3D Tiles data format and WebGL technology. These models help to accurately represent the geometric properties of buildings and other objects and users are able to interactively view and analyse the data in an online environment. This is particularly important for digital construction and efficient project management. Zheng et al. [13] offer a new dataset using professional interior designs and automatically extracting 3D structures. It provides large-scale photorealistic images with rich annotations of 3D structures. The researchers present a generative model that directly generates 3D textured mesh structures with complex topology, rich geometric details and high-quality textures [14].

GM is used in a wide range of industry sectors such as animation, architecture, game development and industrial design. In film and animated series, geometric modelling facilitates the creation of complex characters and environments that appear lifelike and realistic [15].

Two programs, Blender and AutoCAD, are used in the course of GM at VILNIUS TECH. Both give students the opportunity to experiment with different design and model making techniques. Blender and AutoCAD are excellent training programs due to their popularity and a wide range

of applications. AutoCAD is used in the fields of architecture, engineering, and construction, known for its accuracy and ability to create detailed technical drawings. It is also particularly useful for 3D printing, as it facilitates easy editing and optimisation of models to ensure that the final products are of high quality and accuracy. It integrates easily with other Autodesk applications, allowing for a seamless transition from design to production. Meanwhile, Blender makes the creation of more complex 3D models and animations possible, which encourages students to try out new ideas and techniques. Using these applications together, a high level of creativity and technical accuracy can be achieved, which is very valuable in various projects.

However, students' attitudes towards the tasks performed with the software vary (Fig. 4). The 2D Modelling (AutoCAD) task is ranked as the least creativity-enhancing one (5 - 10.4%; 4 - 16.7%). This can be explained by the fact that when students learn precise drawing and editing commands in this program, they do not realise where they can apply it. This can also be linked to the Generation Z trait, where students aim for the fastest possible result with little effort, and associate the purpose of their learning with the benefits they receive. Thus, this result also inspires the lecturer to modify/think about other or more varied processes for the content and delivery of the 2D Modelling (AutoCAD) assignment. Analysing the results further, it can be seen that the Task of Modelling of Puzzle Parts (AutoCAD) is also rated as not very creative (5 - 18.8%; 4 - 12.5%). This is probably also related to the development of specific skills rather than creativity. Of the AutoCAD programmes, only Task of 3D Modelling (AutoCAD) is rated by students as the most conducive to creative thinking (5 - 20.8%; 4 - 25%). It could be argued that AutoCAD tasks are considered by students to be less creative than Blender. The results of the study clearly show that tasks with Blender are significantly more creative: tasks of 3D Animation (Blender) (5 - 81.2%; 4 - 16.7%), 3D Modelling (Blender) (5 - 79.2%; 4 - 18.8%), and 3D Texturing (Blender) (5 - 52.1%; 4 - 22.9%).

Researching students' views on the creativity of tasks would also require knowledge of their relationship to the content of the study subject of GM. Students were asked to rate which topics develop their creativity (Table 1. 1st column). The authors of the article established the links between the topics and the tasks that realise them. The analysis of the results shows that the highest-rated topics are also those in which students specifically use Blender software. These findings are valuable, as they provide insight for adjusting and refining the relevance of the task and intended learning outcomes. On the other hand, the results indicate that the GM course develops diverse competencies due to the variety of tasks used.

TABLE 1. LINKS BETWEEN GEOMETRIC MODELLING (GM) TOPICS AND TASKS

Topics	Tasks
Development and animation of 3D model control systems, surface deformations and visualization.	3D Modelling (Blender) 3D Texturing (Blender)

Topics	Tasks
Model preparation for different environments (18%)	
Creation of free-form geometric surface objects using typical object modelling methodologies (polygons, subdivision surfaces, Metaball). Topology of objects (14%)	3D Modelling (Blender) 3D Texturing (Blender) 3D Animation (Blender)
UV Maps and Texturing. Creating materials for 3D models using texture maps (Diffuse, Normal, Specular, AO, Bump, Roughness, Displacement) (11%)	3D Texturing (Blender)
Creating objects of complex geometric shapes. Applying Bezier curves and NURBS (11%)	3D Modelling (Blender) 3D Animation (Blender)
Precise 3D modelling. Creation of volumetric objects (10%)	3D Modelling (AutoCAD)
Introduction to modelling of three-dimensional geometric objects. Blender user interface. 3D object data structure (7%)	3D Modelling (Blender)
Modelling in AutoCAD (7%).	2D Modelling (AutoCAD)
Application of Boolean operations to model creation. Modifiers (7%)	3D Modelling (Blender) 3D Modelling (AutoCAD)
Preparation of 3D models for 3D printing (5%)	3D Modelling (AutoCAD)
Application of Boolean operations to object creation. Collisions and tolerances of 3D part arrays (4%)	3D Modelling (AutoCAD) Modelling of puzzle parts (AutoCAD)

To form a final opinion on creativity development through the GM course, students were asked the following question: *Do you agree that after completing Geometric Modelling (GM) you will be able to...?* They were presented with 10 abilities corresponding to three different levels of Bloom's taxonomy: understanding, application, and evaluation/creation.

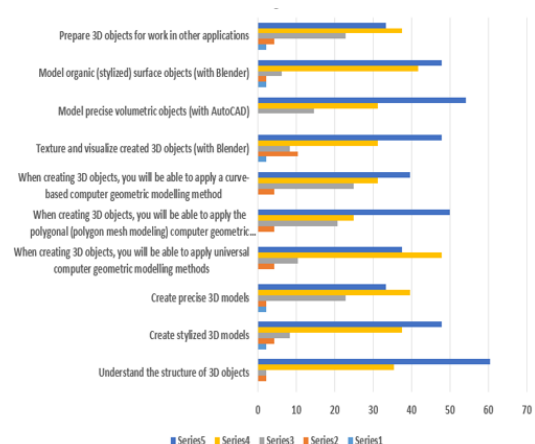


Fig. 5. Abilities that will be developed through the subject of GM (student opinion) (mark from 1 (definitely not) to 5 (definitely yes)).

The results show that students chose the ability "Understand the structure of 3D objects" as the most developed (5 - 60.4%; 4 - 35.4%). The next result is also surprising. The second most developed ability was "Model

precise volumetric objects (with AutoCAD)" (5 - 54.2%; 4 - 31.2%). The paradox is that earlier (Fig. 4) students marked this task as the one least likely to develop creative thinking. It can be assumed that students learn better those tasks which are precise, which are shown and explained by the lecturer in a clear manner, which do not require creative abilities (the level of understanding is sufficient) and the time to complete them. The ability "Prepare 3D objects for work in other applications" scored the lowest percentage (5 - 33.3%; 4 - 37.5%). This ability is associated with interdisciplinarity and a wider context. Thus, there is a trend that creativity education in engineering disciplines requires a different approach, which would be helped by a consistent adherence to the creativity education strands, in particular assessment and reflection on task performance.

IV. CONCLUSIONS

Students consider the study subject of GM, i.e. its content and tasks, to be a real stimulus to the development of their creativity competence. This was underlined by most of the students (75%). However, a few important points can be made when elaborating on this broad view.

Firstly, creativity is not so much inspired by the topics and the objectives of the tasks, but rather by the way in which students pursue these objectives. Attention should not only be paid to the content of the topics and tasks, but to the teaching/learning process itself. Students should be allowed to generate their own ideas about how they will achieve the outcome of the task more often. In particular, the assessment of creativity should be addressed, and students should be provided with opportunities to evaluate their peers' work more and reflect on their own results. The role of the lecturer is therefore very important in the GM subject. Although the lecturers have to work with the computer programs provided to them to teach the content of the subject (i.e. the content of the tasks), they should reinforce and organise the learning process in accordance with the four stages of creativity development. It is also very important that this process of creativity development is consolidated from the first year of studies. This would allow students to continue to develop this competence in the upper years. The researcher [16] encourages the integration of creativity in an interdisciplinary teaching and learning environment, so that students learn and have access to different perspectives. The development of creativity through the integration of creativity into subject competences is a prerequisite for future professionals in the exact sciences, as the development of innovation depends on the abilities they develop. As researchers [17, 18] argue, creativity is the basis for innovation.

Secondly, tasks that are carried out in Blender are perceived by the students as being more conducive to creativity compared to AutoCad. Although it requires more precision and focus, the current generation of Z students should be taught to emphasise its benefits and to show the different products that have been developed using it. In this way, students will see the relevance of the application. Combining both programs in GM is necessary as students have to acquire subject-specific knowledge. However, by

developing creativity competence, they will learn to use subject knowledge to develop innovations or improve what has already been developed. With the aim of exploring how the variety and complexity of subject-specific tasks determine creativity, the study is currently being continued with other groups.

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Reflexion – a Necessary Step in the Process of Solving Mathematics Problems

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Abstract—The rapid development of modern computer science, including artificial intelligence, significantly contributes to the development of engineering technologies. This progress also requires the education of human resources and constant upgrading of qualifications throughout life. However, there are certain problems in the education of future specialists - read - students, which can be seen at the base of fundamental mathematical education. Looking at the national level of Latvia, this is the insufficient number of students in engineering specialities. Another significant problem is the students' incomplete level of mathematical knowledge and excessive reliance on computer technologies. The mathematical preparation of a specialist plays an essential role - one must be able to detect and evaluate possible errors in software, data input and data interpretation, where such errors can lead to critical, even dangerous situations. An engineer must understand the technological process and be able to perform the appropriate mathematical calculations without the use of technology. Evaluation of the obtained results is an essential part of critical thinking, which must be developed during studies. The goal of the current research is to find out whether students analyse the information and evaluate the results of their work, and how the accuracy of the work design impacts the solution. The authors analysed midterm and final exam papers of engineering students to see how they reflected the ability to evaluate the results obtained. The analysis is based on the examination papers of the students of the Faculty of Natural Sciences and Technology of RTU and the Maritime Academy of RTU, which were written during the study of the calculus course.

Keywords— *characteristic faults, engineering students, mathematics, problem solving skills.*

I. INTRODUCTION

At present, there is a great demand in the world for highly qualified engineers who have not only theoretical knowledge of the relevant speciality, but also the skills to apply new technologies, as well as considerable work experience. This creates significant problems for university graduates in the labour market. On the other hand, job providers point to the insufficient knowledge of the young inexperienced specialists. One of the most important

researchers of trades in society, the Organisation for Economic Co-operation and Development (OECD) [1] states:

“Employers and economic organisations express with increasingly louder voices that they are no longer confident that graduates have acquired the skills needed for the 21st-century workplace, in particular, generic skills such as problem-solving, communication, creativity, and critical thinking.”

On the other hand, the fact that an insufficient number of applicants choose to study engineering is causing concern. In [2], the authors conducted the research by studying 11 engineering specialisations in Portuguese universities over a period of more than seven academic years between 2011/2012 and 2017/2018. They found that mathematics and physics entrance exams are the reason why a small percentage, 22%, of university applicants choose to study engineering. They also concluded that the insufficient level of knowledge leads to the fact that students do not attend mathematics lectures and, as a result, drop out. Regarding the organization of studies, the researchers observed that it is not possible to develop mathematical competences such as mathematical thinking, mathematical reasoning, posing and solving mathematical problems and other competences simply by attending math classes.

Quite a lot of researchers [2] - [5] note that high school students have difficulties with learning mathematics due to the low basic knowledge of mathematics, which forms previously structured barriers, low self-assessment, low motivation, and anxiety.

It is a challenge for the academic staff. It is necessary to examine how to create innovative study programmes, how to cooperate with specialists from the industry, which teaching methods should be used and how the knowledge of the students should be evaluated. High schools also need to ensure the students' acquisition of knowledge more carefully.

Online ISSN 2256-070X

<https://doi.org/10.17770/etr2025vol3.8564>

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A. Some Findings about the Engineering Studies in Latvia

The situation is similar in Latvia with regard to engineering studies. Zeideman and Rubina from the Latvia University of Agriculture [6] tested the mathematical competences of the enrolled students in the Engineering Faculty and in the Faculty of Information Technologies. Data was collected on 100 respondents' beliefs about their competences, such as the use of symbolic language, mathematical representation, problem solving and others. The main part of students considered that competences are developed partly. The researchers mentioned students' attitudes towards the study process in terms of participating in class, doing their compulsory homework and completing tests on time. This led to the conclusion that some first-year students, with little mathematical background and without a serious attitude to the learning process, were not ready for university study.

Zvirgzdiņa and Kopeika [7] state that every year there are more young people who have no understanding of mathematical concepts. It reduces the ability of future engineers to create safe, efficient and creative solutions to complex problems that require high level mathematical skills. The authors turn to the State Educational Content Centre underlining the importance of mathematical education and sharing their opinion that only fundamental mathematical knowledge can guarantee the effectiveness of competence-based learning.

To study engineering, applicants need not only motivation but also sufficient knowledge of mathematics. However, if we look at the statistics of students' performance in the central mathematics exams, the results are worrying.

In the centralized high school exam for the 2023/2024 academic year, students achieved an average of 34 percent, one percent lower than the previous year. Out of 59,000 students, 2,700 failed the optimal level mathematics exam. It has to be admitted that a certain problem has been created by distance learning institutions, which show much lower grades obtained by students.

These results also indicate the general level of background knowledge of enrolled engineering students at Riga Technical University (RTU).

Nowadays, the amount of written homework in schools in Latvia has decreased significantly. Some of the work has been replaced by tests. At the end of the test, a student finds out whether he has answered correctly, but there is no analysis - why the answer was wrong, where the mistake was. If during the learning process a student only receives an assessment as feedback without error analysis, the student is not used to looking for errors.

B. Efforts to improve students' mathematical knowledge

There are more questions than answers about the quality of engineering students' education. Different approaches to improving students' mathematical knowledge are recommended by educators around the

world. It largely relates to the study process. This work should be organised to promote active learning attending the lessons, communicating, and working in groups and individually [8]. Charalambides et al [3] suggest that individual differences in students' beliefs, conceptions of mathematics and levels of knowledge should first be assessed. According to the findings academic teachers need to develop teaching materials in problem-solving contexts including real-life problems. A similar opinion has the experts of the MareMathics group [5] indicating that lessons should include attractive learning materials such as video clips, interactive applets, tests, and real-life problems relating to maritime issues. The project's website contains a wide range of teaching and learning materials on the subject, as well as detailed teacher's guides. Pepin et al [4] express similar opinions about the study methods. The quality of the knowledge gained depends on the activities of the students and how deeply they get involved in the innovative practices - modelling, solving open-ended real-life problems and choosing an Actual Student Study Path.

The Mathematical Association of America (MAA) produces up-to-date curriculum guides to assist departments in the improvement of their study programmes [9]. In the introductory part of the guide they underline:

“Students ... should be offered interesting courses that explore the nature of modern mathematics, and its applications Students are attracted to mathematics for its beauty, its utility, and its intellectual merits.” (p. 2)

The Curriculum Guide contains an extensive system of resources, including recommendations from professors and academic teachers at various universities. They advise on pedagogical approaches such as active learning, inquiry-based learning and online homework systems. It is recommended to pay more attention to the underprepared students and to provide them with support and effective teaching to succeed in the mathematics course.

Authors from Aalborg University (AAU) in Denmark share their experiences in leading problem-based learning working groups [10]. In [11] the researchers explain the importance of reflective writing in developing students' critical thinking skills.

An OECD study [1] comparing results in six countries comes to the same conclusion:

“The positive result for lectures and negative result for service learning and field work contradict popular opinions on higher education pedagogy, which favour activating instructional formats. Critical thinking seems to flourish in instruction that requires deep engagement with content, as is the case for lectures, laboratories and seminars.” (p.26)

It is important to note that most researchers and teachers recognise that a significant number of students do not have a sufficient basic knowledge of mathematics. It is necessary to give these students the opportunity to improve and strengthen their mathematical knowledge, skills and methods and to provide them with support.

A supplementary course in elementary mathematics is organised in the engineering faculties of Riga Technical

University. At German universities, students have the opportunity to take a preparatory course for university studies. [12], [13].

II. MATERIALS AND METHODS

A. Basics of the research goal

Today's engineers are expected to be highly skilled, to use new technologies, to implement innovative solutions, to communicate and to use critical thinking to solve various problems. One of the most important aspects in this field is to evaluate the situation, the possible outcome and the achieved result. In many cases, people's lives may depend on it. This is especially true in the maritime industry, but also in the chemical industry, civil engineering and other fields. Much greater safety will be achieved if the specialist does not just rely on the written instructions but is also able to independently assess whether the results obtained are correct.

The evaluation of results is one of the aspects of reflective thinking. Reflective thinking is the process of thinking deeply about a problem, analysing and evaluating it, gaining a deep understanding of the methods used to solve the problem, combining previous experience with new methods, and assessing the outcomes [14]. These are skills that can be trained during the study process as well by solving classic calculus problems.

The goal of the current research was to find whether students analyse the information and evaluate the results of their work, and how the accuracy of the work design affects the solution.

The authors believe that Polya's four-step approach [15], which is recommended for solving mathematical problems, is also useful for engineering students in a calculus course. Reflective thinking can be successfully implemented in each of the steps mentioned:

Step one - understand the problem, step two - make a plan, step three - execute the plan, step four - look back.

The evaluation of the problem solving according to this approach can be divided into three parts:

- The preparation stage (understanding the problem) – evaluate the givens and their relationship,
- The processing stage (devising and carrying out the plan) – evaluate and choose the tools and methods to solve the task,
- The verification stage (looking back to evaluate the results) – answer the given task and evaluate the correctness of the results.

B. Respondents of the research

The respondents are students of the Faculty of Natural Sciences and Technology (FNST) of RTU and students of the Latvian Maritime Academy (LMA) of RTU.

The mathematics course for FNST students lasts 28 weeks. The first part of the course covers limits, continuity,

differentiation, their applications in the analysis of a function and the elements of linear algebra. The second part of the course covers analytic geometry, complex numbers, indefinite, definite and improper integrals, applications of definite integrals. The final examination in the second semester covers ordinary differential equations, differential calculus of functions of several variables, double and triple integrals, series of numbers and functions. For LMA students, the mathematics course lasts 3 semesters and there are written exams at the end of each semester. The topics covered in the mathematics course are similar.

The basic knowledge of mathematics is necessary to acquire this mathematics course. Unfortunately, a significant proportion of students encounter difficulties in their studies. About half of the FNST students scored below 50% in the central exam in recent years. The test on elementary mathematics showed that about 60% of the students need additional teaching in mathematics. The situation is worse for applicants to the LMA. Traditionally, these are students who have graduated from the Maritime School of RTU Latvian Maritime Academy. Here the problem arises from the fact that the centralized mathematics exam is passed two years before receiving the diploma in the subject. In two years, the level of knowledge in mathematics has dropped sharply. 25 students from the Maritime School enrolled in the first course of the LMA in the academic year 2024/2025. They had a significant gap in their mathematical knowledge, as demonstrated by the elementary mathematics test. The other 48 students are high school graduates. Nevertheless, their basic knowledge was not very high on average.

C. Selection of the tasks

FNST students have two mid-term exams after every 8 weeks and one exam at the end of the course. LMA students have final exams after each semester. The exam sets contained 5-7 standard tasks on all topics that the students had studied during the semester or part of it. Students were required to make drawings in their work, they were given grid sheets to make this work easier.

The authors analysed test papers of the students written while studying the calculus course during last 2 years. There were 69 LMA 1st semester and 57 3rd semester students works, and 119 works of FNST 1st midterm exam, 115 of 2nd and 97 works of 3rd exam.

Problems in which the graphical representation is an essential part of the solution, or a way of assessing the correctness of the solution, were selected for analysis. Where this was not required, graphs could be used by students who wished to take a reflective step and check the accuracy of the results they obtained.

From the LMA 1st semester exam problem set, a problem on complex numbers was analysed.

From the first FNST mid-term exam set, 2 problems on the elements of studying a function were selected. Students were offered two types of problems: the first was to find the asymptotes of the graph of a function, and the second

was to find the extrema or inflection points of the graph of another function.

In the second exam, FNST students were given problems in which they had to calculate the area of a plane figure and the volume of a solid of revolution using definite integrals. The problems required a drawing.

In the third examination, students had to solve problems on double and triple integrals. FNST students were offered both problems where they had to calculate the volume bounded by given surfaces and problems where the order of integration had to be changed, which required understanding which region of the plane was used in the given integral, drawing it, and then using the drawing to write the corresponding integral with the opposite order of integration.

The 3rd semester LMA exam contains a task to calculate the volume of a solid. The task also required to recognise given surfaces, to construct the projection of the solid, to develop the system of inequalities that helps to write multiple integral.

D. Methods of the analysis

The authors analysed the solutions, classifying the types of errors and how students acted in situations where they obtained incorrect or impossible results.

Students' analytical skills were assessed indirectly, based on the steps taken in the process of solving tasks. The solutions were analysed according to the questions:

- Did the students understand the given task and the givens,
- Did they implement suitable methods to solve the task,
- Did the students notice obvious imperfections and did they try to correct them.

Noticing that the reason of mistakes for a significant part of students was carelessness or extremely messy writing, researchers paid attention to the quality of the work performed.

III. RESULTS AND DISCUSSION

Some of the FNST exam tasks contained unusual cases, so only a small number of students solved them completely correctly. Some students learn to solve standard problems without delving into the theoretical basis. Consequently, for example, a problem where asymptotes need to be determined for a function with a point of discontinuity of the first kind was not solved correctly in most cases.

Table I shows the success of the solving each type of the task. Solutions with some errors were given by students who would have been able to solve the type of problem correctly at the time of writing the exam, had it not been for carelessness or arithmetic errors.

After reading the problem text, each student could evaluate the givens and their relation to complete Step I, the preparation stage. Step II - evaluating and choosing the tools and methods to solve the task, depends on students'

knowledge. The completion of Step III depends on what has been done previously. This is the reflecting stage, when students look back and assess the reliability of the result.

It was not always possible for students to evaluate their answers. There were cases when no result was obtained, and evaluation was not possible. Table II shows percent of students not evaluating solution steps when it was possible.

TABLE I SUCCESS OF THE SOLVING EACH TYPE OF TASK

Task Type	Correct full solution	Solution with some errors	Have an idea about the solution	Did not solve
Complex numbers	46%	20%	25%	9%
Asymptotes	10%	16%	71%	3%
Extrema or inflection points	32%	9%	48%	11%
Area	40%	30%	29%	1%
Volume of solid of revolution	24%	19%	50%	7%
Double Integrals	35%	14%	33%	18%
Volume using triple integrals	35%	10%	43%	12%

TABLE II PERCENT OF STUDENTS NOT EVALUATING SOLUTION STEPS

Exams	Number of students	Task	Step I	Step II	Step III
I (LMA)	69	Complex numbers	22%	20%	25%
III (LMA)	57	Volume of solid	40%	18%	11%
I (FNST)	119	Asymptotes	10%	71%	40%
I (FNST)	119	Extrema or inflection points	15%	40%	30%
II (FNST)	115	Area	19%	24%	24%
II (FNST)	115	Volume of solid of revolution	21%	37%	22%
III (FNST)	97	Double integrals	18%	35%	35%

The first semester LMA exam included the task of calculating the product or quotient of complex numbers in polar form. An additional requirement was to plot both numbers in the complex plane as radius vectors. 69 examination works were analysed. 46% of the works contained a correct solution, 45% of the solutions were incorrect, and 9% of the works did not contain any solutions at all.

Looking at the incorrect solutions, 20% of all students do not assess the correctness of the result, do not compare the data obtained with the geometric interpretation of the numbers. Among these solutions, the construction was completed incorrectly or not at all in 48% of the works. Superficiality is allowed in the drawings, without specifying the axes of the complex plane (in 17% of the works), as well as without specifying the units of measurement (in 26% of the works). 55% of the incorrectly solved problems look more like a draft due to poor handwriting and many deletions. Some students wrote down the given data incorrectly, others did not simplify the calculations, others used incorrect mathematical notation (in 35% of the works).

In the first exam, only 7% of the FNST students solved both function analysis tasks completely.

The asymptotes problem turned out to be the most difficult. 71% of the students did not calculate limits at the points of discontinuity or did not know how to eliminate uncertainty in a situation where the function has a point of discontinuity of the first kind. The requirement to sketch the graph around the discontinuities was ignored by a significant number of students.

Although the second task of this exam, concerning the extreme points or inflection points, was solved more correctly and only 16% had an incorrect derivative of the function, it is worth noting that 23% of the students did not determine or consider the domain of the function, and almost 39% did not understand what they had calculated. This task did not require sketching the graph, but it was done during the learning process and students could have used the sketch of the graph to understand whether the results obtained were reliable. Students did not take the opportunity to reflect and evaluate the correctness of their work.

In the second exam, solving the area problem, 95% of the FNST students seemed to understand the method of finding the area, but only 40% were able to solve it successfully. In 19% of the cases the students used incorrect integration limits. Some students made mistakes in calculating them, but there were those who did not calculate them at all, trying to read them from the drawing in a situation where one of the limits was not a whole number. It was easy to assess the result of this task if the student was able to draw the graphs of the functions accurately. The quality of the drawings varied, so some students were unable to detect the error in their work. However, even those students who had this opportunity did not use it.

Most of the 14% of students who got a negative number as the area of a figure claimed that the correct answer was the modulus of the resulting number. 24% of the students got the wrong result of the area that was visible different from the correct drawing, but they did not compare the results with the drawing.

The difficulties in calculating the volume of solids of revolution were inserting the function into the formula and

identifying the axis of revolution. Consequently, only 24% of the answers were completely correct. 21% of the students did not evaluate the given quantities and calculated the volume of a different solid of revolution than required.

FNST students learn double and triple integrals in the second semester. In the exam, 35% of the students solved the problems correctly. 18% of the students did not solve the problem. There were major difficulties both in finding the correct domain and in algebraic transformations. Although most of the students drew the graphs of the functions correctly, many of them still had difficulty in understanding which region is described by a given double integral or which region of the plane will be the basis of the volume to be calculated. About 16% of the students successfully solved the integral but made calculation errors.

The final exam of the third semester of LMA included the task of calculating of the volume of a solid. The problem required to detect given surfaces, construct the projection of the solid, develop the system of inequalities that helps to write multiple integral.

There were 57 students' works analysed, 35% of the works contained the correct solution of this task, 53% of the students did not solve the task correctly and 12% of the students did not solve this task at all. When analysing the works with incorrect solution, it was found that more than half of students (in 62% of works, i.e. 28% of all works) did not understand the given - the projection of the solid on the coordinate plane was done incorrectly or not at all. 27% of the papers showed that students did not know how to evaluate the construction and therefore wrote the wrong integral or did not write it at all. Solutions with arithmetical, algebraic or integration errors were 10% of the wrong solutions. Some students got the negative value of the volume of the solid, but they did not check the solution.

The authors found out that a significant part of all students ignored such requirements as detection of the given surfaces (in 54% of all works). Especially in the works with wrong solutions 43% of students did not create the system of inequalities.

It is a bad habit not to write the explanations of the solutions. Such a tendency was observed to a similar extent both in works with a correct solution and in works with an incorrect solution (in 56% of works).

It should be noted that a large part of the students' work was done carelessly. Carelessness manifests itself in ignoring the task's requirements, not writing answers or explanations, using only single phrases, and making inaccurate constructions. The authors also found that correct problem solutions had better written notes and tidier drawings.

5% - 16 % of students made typographical errors, making the task much more complicated, sometimes unsolvable. There were also cases where handwriting was so illegible that the student himself did not understand what

he had previously written. Although neat handwriting does not guarantee a student's ability to solve a problem correctly, there have been cases where extreme messy handwriting has caused a student to fail an exam.

Table III shows some aspects of work design in each type of task.

In a survey of a small portion of the students whose work was analysed by the authors, about 60% of them said that they would revise their work and even redo their calculations if they had enough time. 25% said they knew how to judge whether a solution was correct. 13% said they didn't know what the results should be, and 18% said they relied on luck and didn't check their work.

TABLE III SOME ASPECTS OF WORK DESIGN IN EACH TYPE OF TASK

Task Type	Inaccurate design of construction	Careless math notation	Bad handwriting
Complex numbers	65%	13%	19%
Asymptotes	42%	30%	16%
Extrema or inflection points	-	20%	16%
Area	25%	16%	16%
Volume of solid of revolution	35%	20%	16%
Double Integrals	40%	20%	10%
Volume with triple integrals	71%	29%	23%

IV. CONCLUSIONS

Many students pay very little attention to the analysis of the results obtained, which leads to a situation where a wrong result is displayed even though the student has mastered the algorithms for solving problems. The reason for this behaviour could be impatience - today's young people are used to getting results quickly, but finding an error is a laborious process.

Some students are also hampered in their reflective step by messy or illegible handwriting, which makes it difficult to spot mistakes even when revising the work. As careless mistakes can also lead to emergency situations when a young professional is carrying out tasks, students should be taught to be more careful and to check their work.

As teachers of mathematics courses, the authors of this paper have their own vision. All innovations during the study process must be in balance with the content of the mathematics course and the level knowledge of the students.

To become an expert in the field of speciality, it is necessary to have applicable mathematical knowledge. This can be developed in the following stages:

- Students might have their own experience in solving mathematical tasks and problems, mastering their skills and mastered special and heuristic problem-solving

methods. They must elaborate on basic mathematical knowledge and understanding.

- Having basic knowledge students should use technologies to get wider experience of the interpretations of mathematical results, and to research properties of mathematical concepts.
- To improve cognitive performance students can solve more complex mathematical problems which require deep engagement in the content of the given task.
- Having deeper understanding of mathematics and mathematical results students apply their knowledge to solve real-life problems or engineering tasks using technologies if it is necessary.

In the learning process, more attention should be paid to the evaluation of the results obtained and the presentation of the work. A significant correlation was observed between incorrect solutions and inaccurate design of the work.

It is also important to understand why today's students have insufficient basic knowledge of mathematics to study at the university level. We have observed that the entrants have gaps in the knowledge that had to be learned in primary school, which creates increasingly large gaps in knowledge over several years, as well as causes negative self-esteem and low motivation. We believe that the number of mathematics lessons in schools is insufficient and that teaching methods should be revised.

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Enhancing Mining Education: Integrating Online Learning and Hands-on Experience for Comprehensive Skill Development

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Abstract—The integration of online learning into mining-related education offers significant advantages in terms of accessibility and flexibility. Online learning expands access to specialised education, allowing students from diverse regions to participate without the need to relocate or attend in-person classes. By offering online courses, educational institutions can ensure that students receive up-to-date knowledge, preparing them to address both traditional and emerging challenges in the mining industry. Online platforms provide students with access to a variety of resources, such as lectures, research papers, and interactive simulations, which enhance their understanding of complex mining processes. However, it can be challenging for teachers to engage students online and gauge their level of engagement. Online engagement can be perceived differently than in-class engagement. This article explores interactive learning, which combines online education with hands-on experiences. Students engage in real-world measurements, create models, and apply these models in classroom activities. Online learning promotes self-directed study and offers flexibility. Onsite learning, in turn, allows students to apply theoretical knowledge in practical settings, fostering critical thinking and problem-solving skills. By combining both online and onsite learning, students benefit from a comprehensive educational experience that enhances technical expertise and creativity, ultimately improving learning outcomes.

Keywords— *education, engineers, hands-on learning, mining.*

I. INTRODUCTION

Currently, universities offer various learning opportunities that often allow students to choose the most suitable mode of study according to their personal preferences and educational goals. One such option is online learning, which provides students with flexibility in scheduling and the ability to study independently of geographical location. Another mode of study is traditional on-site learning, where students participate in lectures and practical experiments that are closely related to the specifics of the field being studied. For example, the curricula “Earth Systems, Climate, and Technologies” and “Earth Systems and Geotechnologies” at Tallinn University of Technology (TalTech) offer the opportunity to study both online and on-site. The learning process significantly involves real-world experiments and measurement work. Each mode of study has its advantages and challenges.

The aim of this research is to explore the advantages and challenges of different modes of study, specifically online and traditional on-site learning, focusing on their impact on student flexibility, learning outcomes, and engagement in real-world experiments.

A. LITERATURE REVIEW

With the introduction of the European Union’s Critical Raw Materials Act (the Act) in 2024, there is an onus on academia to deliver courses that will provide specialized

Online ISSN 2256-070X

<https://doi.org/10.17770/etr2025vol3.8515>

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training in sustainable mining practices and advanced technologies. The Act states that the EU must increase its annual needs for the extraction of critical raw materials (CRMs) by 10% by 2030 [1]. In 2020, the global mining industry identified skills shortages as the top risk, with concerns about the future workforce ranking as the second most significant risk [2].

Industry 4.0 significantly impacts education and training [3]. Increasing the adoption of digitalisation, automation and AI, particularly in mining, will require different skill sets [4], [5]. Education will be pivotal in driving sustainable practices, and a comprehensive analysis of the skills required for the mining sector is crucial to achieving the Act's ambitious goals. Therefore, curriculum development is key to ensuring educational programs align with industry needs and future challenges.

One of the major challenges for the sector is balancing resource extraction with the need for greater responsibility and sustainability, especially when extracting metals and minerals for green energy technologies for the EU's Green Deal. Students will require new competencies and be able to develop innovative solutions with an emphasis on environmental and social aspects [6]. With the development of new technologies being tested and implemented in mining, leading to new ways of working, innovative approaches are necessary to prepare students for the sector. The introduction and operation of remote-controlled machinery and robotic or autonomous equipment necessitate a unique skill set, highlighting the need for educational curricula to adapt accordingly [7]. It is no longer sufficient to teach mining engineers solely how to design and operate mines safely and efficiently. The attributes and skills required for mining engineers need to be redefined to address the growing range of diverse and complex responsibilities spanning various disciplines and technologies [8]. Experiential learning, including cooperative education and industrial placements, plays a vital role in engineering programs [9]. These hands-on experiences provide significant benefits, such as enhancing practical skills, bridging the gap between theory and practice, and better preparing students for real-world challenges in their careers.

Only so much can be achieved in the lecture hall or through online course delivery. An integrated approach to developing new skill sets will benefit the students and the industry in the face of the challenges ahead. For instance, hands-on learning through internships at mining sites, simulations of real-world mining operations, and collaborative projects with industry partners provide a more holistic approach to the student's education. These experiences allow students to apply theoretical knowledge in practical settings, understand the complexities of modern mining operations, and develop critical problem-solving skills and, more importantly, employability skills that enhance their marketability [10].

II. MATERIALS AND METHODS

A. Hands-On And On-Site Learning

On-site learning enables students to acquire practical skills by applying the learned theory in real work conditions, providing valuable experience necessary for future employment as a professional in the field. It also offers students the opportunity to directly participate in research and conduct precise measurements, which are essential in the fields of geotechnics and mining.

On-site learning, where students actively participate in lectures, field or laboratory work, and experiments at the university, offers several advantages for both students and instructors and can significantly enhance academic outcomes. For students, on-site learning provides direct involvement in laboratory work and hands-on experiments, allowing them to apply theoretical knowledge in real-world settings. This practical experience is crucial for developing skills that are essential for future professional work. Moreover, students benefit from immediate guidance and feedback from instructors, facilitating a personalised learning experience. This direct interaction allows students to address difficulties and deepen their understanding.

On-site learning fosters direct communication and collaboration with instructors and peers, promoting a strong learning community. Through active participation, students can share insights and perspectives, enriching their educational experience. Additionally, studying on-site enables students to build valuable relationships, creating a support network for future team building, career development, and networking opportunities.

For instructors, on-site learning provides the opportunity to closely observe students' practical work and assess their understanding of theoretical concepts, offering timely support and guidance. This direct monitoring allows for the quick identification and resolution of learning issues, ensuring students stay on track. Instructors can also tailor their teaching approaches to address specific challenges, offering a more personalised and effective learning experience. Furthermore, they can introduce the latest research and technological advancements through laboratory work and experiments, providing students with an up-to-date, hands-on education aligned with industry standards.

On-site learning plays a pivotal role in enhancing academic results by allowing students to apply theory in practice, deepening their understanding and solidifying their knowledge in real-world scenarios. By engaging in active learning, students transition from passive listeners to active participants in research and experimentation, gaining valuable skills and confidence for their future careers. The collaborative environment, where students interact with peers and instructors, helps foster professional relationships and prepares them for the workforce. With continuous, personalised feedback and active involvement in the learning process, on-site learning fosters comprehensive and effective educational outcomes, equipping students

with the practical skills and knowledge necessary for success in their professional lives.

The mining field education at TalTech is closely integrated with practical fieldwork, during which the theory acquired in the classroom is applied in real-world settings. This approach allows students to develop their skills and knowledge, fostering their application in the context of geological and technical analysis, and prepares them for work in the mining sector, where the connection between theory and practice is essential.

In different engineering fields, the ability to bring real-world applications into the classroom varies greatly. For example, in civil engineering, students can easily visit construction sites to observe how buildings, bridges, and roads are constructed. They can see key components like foundations, reinforcement, and structural materials firsthand, making the learning process more tangible.

However, in disciplines such as underground mining engineering, replicating practical experience within a classroom environment presents significant challenges. Mining operations often occur in remote, deep, and hazardous environments, making site visits logistically challenging and sometimes unsafe for students. Unlike construction, where elements are visible and accessible, mining involves complex processes happening out of sight, deep beneath the earth's surface. To bridge this gap, educational institutions must rely on virtual simulations, 3D models, and case studies to convey the realities of underground mining (Fig.1).

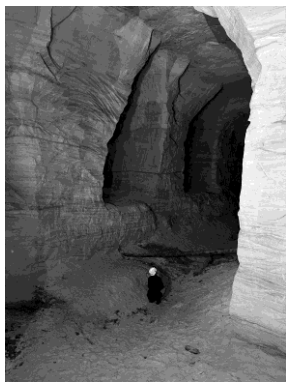


Fig. 1. Student Practical Experience and Measurements for Creating a 3D Model: Piusa Sand Caves, Estonia (Photo by S.Kanter).

Virtual simulations (Fig.2) and laboratories play a crucial role in modern mining education by leveraging advanced simulation and virtual reality technologies. These tools allow students to model mining processes and address practical tasks in a controlled, safe environment.

By using virtual simulations, students can gain valuable hands-on experience without the risks associated with real-world mining operations, enhancing their understanding of complex scenarios and improving their problem-solving skills in mining processes (Fig.2.).

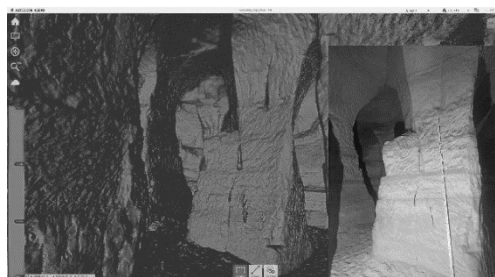


Fig.2. 3D Model Created After On-Site Measurement: Piusa Sand Caves, Estonia (by S. Kanter).

While these tools help, they cannot fully replicate the immersive, hands-on experience that on-site learning provides in other engineering disciplines.

B. Practical Experience In Mining Studies

The integration of theoretical studies with research and practical experience for mining students can be effectively achieved through various approaches.

C. Practical Fieldwork, Excursions, Collaboration With Industry

Organizing regular visits to operational mines enables students to become acquainted with a variety of mining technologies, observe work processes firsthand, and engage in practical activities. These experiences offer invaluable exposure to real-world mining operations. Furthermore, establishing partnerships with mining companies facilitates opportunities for students to participate in internships and research initiatives. This includes summer internships, where students contribute to real projects within mining operations.

Encouraging students to participate in research projects that integrate mining, geology, environmental science, and engineering is crucial for their academic and professional development. These interdisciplinary initiatives allow students to make meaningful contributions to key areas such as mining sustainability and the efficient utilization of geological resources. A notable example of such an initiative is the involvement of master's students from TalTech's Department of Geology in a collaborative project with university researchers, titled "Expanding the Reuse of Mined Areas and Mining By-products." This project aimed to address the environmental impact of residual pollution resulting from oil shale mining. The primary objective was to develop technical solutions for stabilizing the ground in old and closed mining areas, considering critical factors such as mining depth, extraction methods, and the thickness of the overburden layer. (Fig.3). This research not only provides valuable insights into sustainable mining practices but also offers students hands-on experience in tackling real-world environmental challenges. As a result of the study and pilot work, guidelines for the reuse of undermined land were developed, tailored to the specific mining and geological conditions of the subsurface in different areas. A standardized solution for the re-utilization of depleted areas

was also designed, along with environmental and safety requirements for these sites.



Fig.3. Students' hands-on experience in tackling real-world environmental challenges (Photo by H. Klaas).

D. Lectures By Industry Representatives

Guest lectures and seminars delivered by representatives of the mining industry are a vital component of mining education, providing students with direct insights into the current challenges and innovations within the sector. By inviting industry professionals as guest lecturers, universities offer students the opportunity to engage with experts, familiarize themselves with the latest trends and technologies, and develop a deeper understanding of practical mining operations. These interactions serve to bridge the gap between academic theory and industry requirements, thereby equipping students for future careers in the mining sector.

Integrating practical and theoretical knowledge in mining education offers students a comprehensive understanding of the industry. By combining hands-on experiences, such as fieldwork, internships, and research projects, with academic coursework, students gain deeper insights into mining operations, technologies, and challenges. This approach not only enhances their technical expertise but also prepares them for diverse career paths in both mining operations and research. The integration of practical experience with theoretical learning equips students with the essential skills to address real-world issues and contribute to the future advancement of the mining sector.

E. Online Learning. Its Pros And Cons

For today's learners who wish to participate in university courses through online platforms, particularly in specialised fields such as mining, numerous advantages make the learning experience more convenient and efficient. One of the key benefits is the flexibility it offers in scheduling. Online courses allow students to decide when and where they work with the course materials. This is particularly beneficial for those who need to balance their studies with other daily responsibilities, such as work, family life, or other obligations. For students in the mining industry, this flexibility is especially useful, as they may work in remote areas or on shifting schedules were

attending traditional in-person classes could be difficult. Learners no longer must worry about adhering to a specific class time or being present physically, as they can engage with the materials at a time and place that suits them best.

Additionally, online courses often provide easier access to learning materials, which is particularly relevant for technical fields like mining. Students can access specialised resources such as industry reports, technical papers, simulation software, and video demonstrations anytime and from any location. This makes the learning process much more flexible and adaptable to the student's needs. For those in the mining industry, this access allows them to learn in-depth about mining technologies, safety protocols, environmental regulations, and resource management while continuing to apply their knowledge on-site. This makes online learning not only more accessible but also more directly applicable to real-world situations in the mining sector.

Since there are no mandatory class times or required physical attendance in an online course, learners are better able to tailor the learning process to their personal goals and learning styles. This provides them with greater control over their studies, promoting independence and motivation. Students can learn at their own pace, taking the time to thoroughly explore complex topics such as mining engineering, geology, sustainable practices, or mine safety, or move more quickly through simpler materials. This freedom allows for a deeper understanding of specialised subjects and a higher quality learning experience.

The disadvantages of fully online university learning are that there are no live contact hours, even though online tools, and students are expected to work independently through the provided materials, including a lack of direct interaction. This setup means students miss the opportunity to ask questions and receive immediate feedback, as there is no mandatory presence, and they can plan their own schedules. There is also limited peer engagement, with students potentially feeling isolated and missing the benefits of learning from their peers. Self-motivation and discipline become crucial, and some students may struggle to stay on track without structured class times, leading to procrastination or an incomplete understanding of the material. Furthermore, networking opportunities are reduced, as online learning may limit the chance to build relationships with professors and fellow students, which are often valuable for academic and professional development. Students may also find it difficult to master complex topics without the guidance and support that face-to-face or live interactions provide. There are also technical issues to consider, as students may experience connectivity problems or lack access to the necessary tools for online learning. Lastly, accountability and assessment can become concerns, as it may be harder for instructors to ensure that students are truly engaging with the material and completing the work independently without the structure of in-person sessions.

In short, while the flexibility of fully online learning is advantageous, these challenges can hinder effective learning for some students.

TalTech currently offers the master's course CircPro, "Circular Economy for Materials Processing," which provides a comprehensive overview of the raw materials value chain. The course covers all stages, from exploration and mining to processing, manufacturing, material recycling, and re-use, all framed within the context of resource efficiency and circular economy principles. The primary objective is to equip future engineers with the necessary knowledge and skills to develop sustainable processes throughout raw materials value chains. Open to all students with an interest in the subject—no prior knowledge required—CircPro has gained significant popularity both locally and internationally in recent years. It is available to EuroTeQ students and is also part of TalTech's micro-degree program, "Sustainable Exploration, Mining, and Circular Economy of Mineral Resources." By enrolling in any of the micro-degree programs, professionals can build upon their existing academic background and acquire specialized expertise, thereby enhancing their skills and competencies for career advancement or further academic pursuits.

The previously mentioned course "Circular Economy for Materials Processing" offers students a comprehensive understanding of the entire raw materials value chain, with a specific focus on metals and minerals from a resource efficiency and circular economy perspective. Utilizing a "flipped classroom" teaching method, students first engage with the foundational concepts of the raw materials value chain through virtual lectures, videos, and quizzes. This approach aims to build students' knowledge and capacity in the latest circular economy practices and resource efficiency techniques. By the end of the course, graduates will be well-equipped to address sustainability challenges in materials processing and contribute to the development of more sustainable practices in the industry.

III. RESULTS AND DISCUSSION

Nowadays, online courses have gained significant popularity due to their flexibility, enabling participants to better manage their time and select the most convenient moments to engage with study materials. Unlike traditional classroom settings with fixed schedules, online courses offer the freedom to learn at one's own pace. This flexibility is especially beneficial for individuals with busy lifestyles, as they can choose when and where to study—whether in the morning, during lunch breaks, or late at night—adapting their learning around personal commitments. Furthermore, the ability to revisit materials as needed provides a more personalized and efficient learning experience, allowing learners to review challenging topics without the time constraints often present in conventional classes.

IV. CONCLUSIONS

Universities today offer a range of learning opportunities, with online and traditional on-site learning being two of the most prominent modes of education. Each

method has distinct advantages and challenges that impact student flexibility, learning outcomes and engagement in real-world applications, particularly in specialized fields like mining. On-site learning provides students with the invaluable opportunity to apply theoretical knowledge in real-world settings, offering hands-on experience in labs, fieldwork and research projects. This immersive, practical approach fosters a deeper understanding of concepts and enhances students' preparedness for professional work. However, challenges such as logistical difficulties in replicating complex environments like underground mining must be addressed through innovative solutions, such as virtual simulations and industry collaborations.

On the other hand, online learning offers flexibility and convenience, allowing students to learn at their own pace and access materials from anywhere, making it ideal for those with busy schedules or working in remote areas. While this mode enables greater independence and adaptability, it also comes with its own set of challenges, including limited peer interaction, lack of direct instructor feedback, and the potential for student isolation. Additionally, fully online courses may struggle to provide the immersive, hands-on experience necessary for fields requiring practical skills like mining.

The integration of both on-site and online learning models, supported by real-world applications such as internships, fieldwork, and industry collaboration, is essential for ensuring that students gain both theoretical knowledge and practical expertise. This hybrid approach can better prepare students for the rapidly evolving demands of industries like mining, where sustainability, innovation, and advanced technology play a crucial role. Considering the growing importance of sustainability and the increasing complexity of industries such as mining, universities must continue to adapt their curricula and teaching methods to meet these challenges and provide students with the skills necessary to thrive in their future careers.

By leveraging the strengths of both modes of study - online learning's flexibility and on-site learning's hands-on experience - students can benefit from a well-rounded education that not only meets the needs of the industry but also aligns with their personal learning preferences and professional goals. The ongoing development of innovative learning tools, industry partnerships, and research initiatives will ensure that students are equipped to address the complex challenges ahead, particularly in fields like mining that are integral to the future of sustainability and technological advancement.

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Artificial Intelligence as a Support Tool in Teaching Programming to Future Bachelor's Students of Vocational Education

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Abstract- The article presents a thorough examination of the potential applications of artificial intelligence (AI) in supporting the instruction of programming to future bachelor's degree students in vocational education. It explores the pivotal domains of AI integration into the educational process, encompassing the utilization of adaptive learning systems, intelligent tutoring systems, automated code evaluation systems, and generative models that enhance both the theoretical and practical training of students. It demonstrates the ways in which AI enhances the personalization of educational content, facilitates rapid feedback loops, and optimizes the verification process of software solutions. It has been determined that the integration of AI facilitates the creation of adaptive learning environments. In such environments, automated algorithms analyze test results, the history of students' interaction with educational materials, and the personal pace of information assimilation. Consequently, this facilitates the development of customized educational pathways that are tailored to the distinct characteristics of each student. The implementation of intelligent tutoring systems, such as ChatGPT, GitHub Copilot, or Google AI Studio based on Gemini, facilitates the elucidation of complex programming concepts, including the principles of recursion, sorting algorithms, and other fundamental principles. This, in turn, contributes to the cultivation of critical thinking and self-study skills. In the article, the authors analyze the challenges associated with the introduction of AI in the educational process. The primary challenges identified pertain to issues of academic integrity, particularly when future bachelor's of vocational education employ AI capabilities to automatically generate solutions without a comprehensive grasp of the subject matter.

Additionally, the article addresses technical limitations concerning the substantial computing resources required and the integration of contemporary algorithms into existing educational platforms. The article further underscores the necessity for specialized professional development programs to equip educators with the skills to effectively utilize AI in vocational education. Additionally, it emphasizes the establishment of ethical frameworks to guide the implementation of AI technologies in this context, ensuring that the principles of academic integrity are preserved and the integrity of the educational process is maintained. The authors of the article propose a number of recommendations and approaches to optimize the process of AI integration, create integrated learning environments, and improve existing assessment methods with regard to automated code verification. The findings of the study can be utilized to enhance pedagogical approaches in programming, to improve the quality of training in the field of information technology, and to promote the development of competitive graduates.

Keywords- Artificial Intelligence, vocational education, programming training, adaptive learning systems.

I. INTRODUCTION

In the contemporary context, marked by the proliferation of digital technologies and the rapid transformation of the labor market, there is an imperative to enhance the pedagogical approaches employed in the training of future bachelor's degree holders in vocational education specializing in programming. Conventional

Online ISSN 2256-070X

<https://doi.org/10.17770/etr2025vol3.8537>

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teaching methodologies encounter a myriad of challenges, including a paucity of personalization, an absence of prompt feedback, and the inability to effectively validate students' software solutions. In this milieu, the integration of AI holds considerable potential to transform the learning process by rendering it adaptive, efficient, and technologically agile.

Specifically, AI stands as a pioneering instrument capable of substantially enhancing the caliber of programming education. The field of AI encompasses the development of intelligent machines and systems, endowed with the capacity to execute tasks formerly relegated to human intelligence. Such tasks include learning, data analysis, pattern recognition, decision-making, and natural language processing. The field of AI is founded on machine learning, deep learning, and other methodologies that empower systems to adapt to novel data and enhance their performance without the necessity of explicit programming [1]. The capabilities of adaptive learning, automated code review, the generation of personalized tasks, and instant feedback are instrumental in facilitating the creation of an effective learning environment that caters to the distinct needs and training levels of each student. The integration of AI in programming education has been shown to facilitate knowledge assimilation, cultivate critical thinking skills, and enhance self-study abilities, as well as the capacity to swiftly adapt to emerging technologies [2].

Moreover, the integration of AI into the educational process is congruent with global trends in education, including the transition to digital and interactive teaching methods. This is of particular significance for the training of future professionals, who must be prepared to function in a context of constant innovation and change. Consequently, the exploration of the potential of leveraging AI as a pedagogical tool to support the instruction of programming for future bachelor's degree programs in vocational education is of paramount importance. This initiative is directed towards addressing the pressing challenges encountered in contemporary education and enhancing the employability of graduates in the labor market.

II. MATERIALS AND METHODS

The integration of AI into the educational process has been widely discussed in recent research, with a particular focus on its application in programming instruction. Studies by Luo et al. and Zawacki-Richter et al. emphasize the potential of AI to enhance personalized learning, optimize assessment methods, and reduce the workload of educators through automated grading and knowledge adaptation. AI-driven systems facilitate predictive analytics, enabling the identification of students requiring additional support, and contribute to the development of adaptive learning environments that adjust task complexity based on individual proficiency levels.

This study employs a systematic literature review and comparative analysis of AI-powered educational tools to evaluate their role in programming education for future

bachelor's degree students in vocational education. The literature review includes peer-reviewed articles indexed in Scopus, IEEE Xplore, and Web of Science, with a focus on research published between 2019 and 2024. Particular attention is given to studies by Shevchenko et al. and Lytvynova et al., which explore the effectiveness of AI in automating programming task evaluation and providing tailored recommendations for code improvement. Additionally, the study examines practical AI implementations such as intelligent tutoring systems, automated assessment platforms, and AI-assisted integrated development environments.

The research methodology also involves a qualitative analysis of AI applications in programming education, drawing on previous empirical findings. The study evaluates AI's impact on student engagement, learning efficiency, and problem-solving skills while considering potential challenges related to academic integrity, instructor preparedness, and technological constraints. The findings contribute to a broader understanding of AI's role in vocational education and provide recommendations for its effective implementation in programming instruction.

III. RESULTS AND DISCUSSION

A review of the extant scientific literature reveals the considerable promise of AI in the domain of programming education. Notwithstanding, concerns regarding methodological support, the development of effective adaptive learning algorithms, and the ethical considerations of AI in the educational process persist. AI has been demonstrated to play a pivotal role in enhancing the learning of theoretical programming fundamentals through adaptive learning, intelligent tutoring systems, and automated support for students [1]-[5].

The integration of AI within educational settings has been shown to enhance personalization of learning experiences, boost student engagement, and alleviate cognitive load by automating the delivery of explanations and feedback. A particularly salient domain within the realm of AI in education is that of Intelligent Tutoring Systems (ITS), which are designed to provide customized assistance to students. Empirical evidence has demonstrated the efficacy of ITS in emulating teacher behaviors, assessing student progress, and tailoring explanations to align with each student's level of understanding [7].

AI assistants such as ChatGPT, DeepSeek, and Gemini have the capacity to respond to students' inquiries in real time, elucidating theoretical programming concepts in a comprehensible manner. These assistants employ Natural Language Processing (NLP) and machine learning algorithms to generate comprehensive explanations of intricate subjects. For instance, a student can inquire about the principles of recursion, and the system will not only define the concept but also furnish code examples, identifying the aspects that may present a significant challenge for a specific user.

To demonstrate the potential of AI-driven tutoring systems in programming education, the authors have

developed a specialized prompt designed to enhance AI-assisted instruction. This prompt enables AI assistants to provide structured, beginner-friendly explanations tailored to vocational education, integrating theoretical knowledge with practical applications.

For instance, when teaching conditional statements (if, else, elif) in Python, the AI is instructed to define the concept in simple terms, present a workplace-related example—such as automating a temperature check in a manufacturing setting—and offer a relevant code snippet. The AI then encourages the student to apply the concept by composing a conditional statement for a vocational task, such as verifying safety protocols. If difficulties arise, the AI breaks the problem into smaller steps and provides corrective feedback with step-by-step explanations, reinforcing the connection between programming skills and their future profession.

The following is an excerpt from the AI prompt developed in this study:

"You are an AI assistant designed to support students in learning programming for their future careers. Your task is to explain programming concepts in a clear, beginner-friendly manner, provide real-world examples relevant to vocational tasks (e.g., automation, data analysis), and guide students through hands-on coding exercises. Use an encouraging tone, correct mistakes with step-by-step explanations, and link concepts to practical job-related applications."

Focus on conditional statements (if, else, elif) in Python. Start by defining the concept in simple terms. Provide a workplace example (e.g., automating a temperature check in a manufacturing environment). Include a code snippet. Then, ask the student to write a conditional statement for a vocational scenario (e.g., verifying safety protocols). If they struggle, break the problem into smaller steps. Highlight how mastering this skill applies to their future profession."

This structured interaction demonstrates how AI-driven assistants can bridge the gap between theoretical programming knowledge and industry-relevant applications, fostering a more intuitive and career-oriented learning experience for vocational students (Listing 1).

```
# CONDITIONAL STATEMENTS IN PYTHON
# Scenario: Temperature Monitoring in Manufacturing
# Why this matters: Automating safety checks reduces human error.
# Simulate a machine's current temperature (in Celsius)
current_temp = 145
# Check if temperature exceeds safe upper limit (150°C)
if current_temp > 150:
    print("⚠ Warning: Temperature too high! Shutting down.") # Trigger emergency protocol
```

```
# Check if temperature is below safe lower limit (100°C)
elif current_temp < 100:
    print("⚠ Warning: Temperature too low! Adjust settings.") # Alert for calibration

# If temperature is within safe range else:
    print("✅ Temperature normal. Operation continues.") # Confirm stable conditions
# STUDENT TASK: SAFETY PROTOCOL VERIFICATION
# Vocational context: Manufacturing/Industrial Settings
# Goal: Ensure two safety protocols are met before machine startup.
# Step 1: Define safety status variables (modify values to test)
goggles_on = True # Safety goggles must be worn
emergency_stop_working = True # Emergency button must be functional
# Step 2: Write a conditional to check BOTH protocols
# Hint: Use 'and' to require both conditions to be True
if goggles_on and emergency_stop_working:
    # Display success message if both are True
    print("✅ Safety protocols met. Machine starting.")
else:
    # Display failure message if any condition fails
    print("❌ Safety check failed. Investigate and retry.")

# Career connection: Such checks prevent accidents in factories.
```

Listing 1. Prompt result illustrates how AI-powered tutoring can support students in mastering conditional statements by providing clear explanations.

A study by Zawacki-Richter et al. demonstrates that the incorporation of intelligent tutoring systems into the educational process enhances learning efficiency. This enhancement is attributed to the ability of AI to provide customized explanations and immediate feedback, representing a substantial advancement over conventional teaching methods.

The implementation of adaptive learning, facilitated by AI, enables the adjustment of the complexity of theoretical materials to align with the individual student's level of knowledge. This enhancement in learning efficacy is attributable to the analysis of test results, the history of interaction with educational materials, and the rate of information assimilation. To illustrate, in the event that an intelligent tutoring system detects a student's inability to comprehend the principles of loops in the Python programming language, the system can offer

supplementary explanations, interactive exercises, or alternative approaches to learning the topic. The utilization of AI in this context is predicated on the application of machine learning and cluster analysis methods to identify patterns in students' learning achievements.

This approach enables the creation of customized learning pathways, a critical factor in the development of programming competencies. The study by Luo et al. corroborates the efficacy of adaptive learning systems leveraging AI in adapting learning resources to the distinct needs of students, thereby enhancing the quality of learning [2].

The integration of AI within programming education has been identified as a significant advancement, particularly in the context of error correction. This capability is particularly beneficial during the initial stages of learning, when students frequently encounter challenges in identifying syntactic and logical errors in code. According to a study by Lytvynova et al. the incorporation of AI into Integrated Development Environments (IDEs) facilitates automatic code analysis and the provision of immediate error explanations [5].

For instance, AI-enabled development environments (e.g., JetBrains AI Assistant, GitHub Copilot) offer explanations for specific code fragments, recommendations for optimizing algorithms, and even step-by-step instructions for fixing errors. It is noteworthy that contemporary educational platforms such as CodeSignal, Mimir Classroom, and CodeGrade employ AI algorithms to analyze students' code in real time.

This facilitates not only the evaluation of task accuracy but also the generation of comprehensive reports that assess the strengths and weaknesses of the code, thereby enhancing learning efficiency. Intelligent tutoring systems, adaptive platforms, and automated hints serve to mitigate barriers to learning complex concepts by offering more effective feedback and a more flexible management of the learning process. Notwithstanding the numerous benefits, the quality of automatically generated explanations, the level of academic integrity, and the need to train teachers to effectively utilize AI in teaching remain significant concerns [6].

The integration of AI into the educational process has emerged as a significant paradigm shift, with the potential to enhance the learning of theoretical programming fundamentals. This integration encompasses the implementation of adaptive learning methodologies, intelligent tutoring systems, and automated support for students, thereby personalizing the educational experience and enhancing student engagement. The incorporation of AI-driven systems automates the delivery of explanations and feedback, thereby reducing the cognitive load on students and facilitating a more efficient learning environment. The assessment of learning outcomes and the provision of effective feedback constitute pivotal aspects of cultivating students' professional competencies.

In the context of traditional programming education systems, the process of code review and error analysis is often labor-intensive and time-consuming for teachers. The integration of AI to automate these processes can enhance efficiency, reduce grading delays, and personalize the educational experience.

While AI-driven automation addresses inefficiencies in instructor-led evaluation, its potential extends beyond administrative streamlining. Modern AI tools, such as conversational assistants (e.g., ChatGPT, Gemini) and code-centric platforms (e.g., GitHub Copilot, JetBrains AI Assistant), further enrich programming education by providing dual-axis support: they alleviate instructor workload and empower students through real-time, context-aware guidance. These tools diverge in functionality—conversational AI excels at conceptual scaffolding and adaptive problem-solving, while code-centric systems optimize practical implementation and syntax precision.

The following analysis categorizes their distinct educational applications (Table 1), demonstrating how their complementary roles bridge theoretical understanding and vocational skill development. For instance, AI not only automates error detection but also transforms mistakes into teachable moments, fostering iterative learning cycles that mirror real-world software debugging processes.

TABLE I. COMPARATIVE ANALYSIS OF AI TOOLS FOR PROGRAMMING EDUCATION

Service	Main Features	Advantages
ChatGPT/ Gemini	Natural language interaction, concept explanation, debugging guidance, personalized learning support.	Accessibility, adaptability to diverse skill levels, promotes self-directed learning.
GitHub Copilot	Code autocompletion, real-time suggestions, IDE integration, multi-language support.	Enhances productivity, reduces syntax errors, ideal for project-based learning.
JetBrains AI Assistant	Context-aware code generation, refactoring tools, error detection within IDEs.	Seamless integration with professional tools, supports advanced vocational workflows.

A study [8] found that the integration of AI in the evaluation of practical tasks has a positive impact on students' academic performance. This is due to the immediate feedback provided by AI systems, which enables students to swiftly correct errors. Additionally, AI systems can adapt the complexity of tasks to suit the unique needs of each student, enhancing the efficiency and personalization of the learning.

Automated assessment systems facilitate not only the evaluation of task correctness but also the assessment of programming style, the efficiency of algorithms, and the alignment of code with contemporary standards [8]. For

instance, CodeGrade integrates with Learning Management Systems (LMS) to automatically analyze code, verify its alignment with course requirements, and generate reports for students and teachers.

A study by Dunder et al. demonstrated that the integration of AI into automated assessment systems leads to a substantial reduction in teachers' workload, enabling them to allocate more time to methodological and advisory activities. Moreover, the automation of the assessment process fosters objectivity and standardization, which are crucial factors in ensuring the quality of education [7].

One of the primary benefits of incorporating AI within the context of programming education is the capacity to provide immediate feedback. AI-based tools are capable of not only identifying errors in code but also elucidating their underlying causes and proposing potential solutions. For instance, GitHub Copilot analyzes code and offers recommendations for optimization, while JetBrains AI Assistant integrates with integrated development environments (IDEs) to assist with programming writing and debugging.

A study by Frankford et al. found that students who utilize AI for automated assessment demonstrate accelerated progress in learning programming languages. This is due to the ability to promptly obtain explanations for errors and make corrections [9]. However, it is important to note that excessive reliance on AI can diminish the level of independent critical thinking. Therefore, the effective use of these technologies necessitates a balanced approach that incorporates automated support with personal code analysis.

Notwithstanding its myriad advantages, the utilization of artificial intelligence in the domain of code review automation is encumbered by certain limitations. The primary limitations pertain to the following:

1. The potential for erroneous evaluation of complex algorithms: Contemporary AI systems demonstrate proficiency in recognizing syntactic and logical errors. However, they may erroneously interpret complex algorithmic structures and innovative approaches to problem-solving.

2. Concerns regarding academic integrity: Students may employ AI to automatically generate responses without comprehending the theoretical underpinnings, thereby jeopardizing profound learning.

3. The necessity to adapt curricula is also imperative, as the integration of AI into the educational process necessitates alterations in teaching methodologies and educational materials, which in turn requires the appropriate training of teachers. In our estimation, the introduction of AI in automated code review and feedback represents a promising domain of educational technology development with the potential to considerably enhance the efficiency of programming education. Concomitantly, it is imperative to take into account potential challenges and

devise strategies to overcome them in order to ensure a balanced utilization of these technologies.

The integration of AI into the professional education of future bachelor's degree programs in vocational education is a promising area, but it is accompanied by a number of challenges and limitations. Despite significant advancements in the field of AI development, technical limitations may affect its effectiveness in teaching programming. For instance, studies have demonstrated that contemporary models such as ChatGPT can effectively solve simple tasks but encounter challenges when confronted with more complex programming problems. In the study titled "Kattis vs. ChatGPT: Assessment and Evaluation of Programming Tasks in the Age of Artificial Intelligence," [7] ChatGPT was able to solve only 19 out of 127 programming tasks provided by the Kattis automatic evaluation system, indicating its limited capabilities in complex scenarios.

However, the rapid evolution of AI technologies suggests that such findings may quickly become outdated as newer, more capable models emerge. Research by Jošt et al. highlights this shift, demonstrating that modern large language models LLMs exhibit enhanced performance in programming education, particularly when utilized as support tools [10]. Their study, involving undergraduate students learning React applications, found that reliance on LLMs for complex tasks, such as code generation and debugging, negatively correlated with final grades (Spearman's $\rho = -0.305$, $p = 0.045$; $\rho = -0.360$, $p = 0.021$), whereas their use for supplementary explanations showed no significant adverse effect ($\rho = -0.201$, $p = 0.135$) [1]. These results suggest a growing potential for LLMs in vocational education, provided their application is judiciously balanced.

Nevertheless, the findings of earlier studies, such as the 2019 ChatGPT evaluation, should not be overemphasized, as they reflect AI capabilities at a specific point in time. Jošt et al. emphasize that the advancing capabilities of LLMs necessitate a reevaluation of their educational role [10]. As AI progresses, with models demonstrating increased proficiency in addressing complex programming challenges, educators must adapt pedagogical strategies to leverage these tools effectively. This approach ensures that AI enhances, rather than overshadows, the development of essential programming skills, aligning with the evolving demands of vocational education.

The integration of AI into the educational process necessitates a reevaluation of conventional pedagogical approaches. Teachers must adapt their teaching methods to effectively utilize AI as a support tool. This underscores the imperative to develop novel teaching strategies that take into account the capabilities and limitations of AI, as well as the necessity to train teachers to utilize these technologies. The incorporation of AI in education gives rise to concerns regarding ethics and privacy. The collection and analysis of student data may raise concerns about privacy and security of information. Furthermore,

there is a risk of students' overdependence on AI, which may negatively affect the development of their critical thinking and independent problem-solving skills. The study [7]-[9] points to the need to balance the use of AI and traditional teaching methods to ensure the comprehensive development of students.

The implementation of AI necessitates substantial resources, including advanced computing systems and access to voluminous data sets. Not all educational institutions possess the requisite infrastructure and financial resources to undertake such endeavors, which can result in disparities in access to contemporary technologies among students across different institutions. The rapid advancements in AI technologies demand incessant updating of teaching materials and adaptation to novel tools and methodologies. Teachers must be prepared to engage in continuous learning and enhancement of their skills to effectively integrate AI into the educational process.

The advent of AI as a pedagogical tool for the instruction of programming in the context of vocational education has the potential to significantly enhance the efficacy of the educational process. However, the effective integration of AI technologies necessitates further research, the adaptation of curricula, and the implementation of innovative teaching methodologies. The development of AI in programming education presents several key prospects, among which are the following.

The development of adaptive educational platforms leveraging AI will facilitate the precise alignment of educational material to the distinct needs of each student. Contemporary systems already employ machine learning methods to assess students' knowledge and progress; however, their capabilities can be augmented by incorporating more sophisticated neural networks and prediction algorithms [8].

It is anticipated that future advancements in AI-powered assistants within the domain of programming education will extend beyond mere code explanations to encompass the identification of optimal learning strategies for each student. These strategies will be determined through comprehensive analysis of students' historical experience and cognitive styles. Platforms such as Microsoft's IntelliCode and JetBrains' AI assistants are progressively aligning with this direction by incorporating progressively sophisticated intelligent features, thereby providing enhanced support to novice programmers.

AI has already been incorporated into the development of automated code review systems, yet there is ample room for enhancement. Presently, the evaluation of code quality and compliance with best programming practices is primarily conducted by existing platforms, which focus on syntactic and logical correctness. However, future advancements may encompass the analysis of code quality and adherence to optimal programming methodologies [9].

The subsequent phase may entail the creation of AI systems that not only verify the correctness of code but also educate students by offering recommendations for

enhancing the efficiency, readability, and optimization of code. The integration of generative models such as GPT-4, Gemini, and Claude into programming education represents a promising avenue for advancement. These models have the potential to function not only as assistants for writing code, but also as interactive tutors that elucidate programming concepts, assist with code debugging, and model real-world software development scenarios. For instance, the integration of generative AI into IDEs (Integrated Development Environments) has the capacity to enable students to receive instant code explanations and predictions of possible errors before the program is launched. This approach has the potential to markedly increase the efficiency of learning and render the process of learning programming more intuitive.

In light of the extant literature on the subject, the following recommendations are put forth for the advancement of AI integration in the realm of programming education:

1. The establishment of integrated learning environments that seamlessly integrate adaptive courses with automated code verification mechanisms.
2. The development of assessment methods that leverage AI capabilities, including the verification of the uniqueness of program logic.
3. The implementation of professional development programs for educators that will empower them to utilize AI in an effective manner within the educational process.
4. The development of national policies on the use of AI in professional education to regulate academic integrity and ethics of AI use. In conclusion, the integration of AI into programming education holds great promise; however, a comprehensive approach and close cooperation between technology developers, teachers, and educational researchers are essential for its successful implementation.

IV. CONCLUSIONS

This study underscores that the incorporation of AI into vocational programming education holds considerable transformative potential, enabling a shift from traditional, one-size-fits-all instruction to a more personalized and adaptive learning paradigm. The analysis indicates that AI can significantly enhance learning efficiency and student engagement by facilitating real-time, individualized feedback and dynamically tailoring educational content.

However, the findings also highlight the need for a balanced implementation approach that addresses inherent challenges, such as ensuring academic integrity, overcoming technical limitations, and equipping educators with the necessary skills to harness these technologies effectively. Rather than merely automating existing processes, the successful integration of AI should be viewed as part of a broader pedagogical reform. This reform involves revising curricula to incorporate AI-driven assessment tools and adaptive learning environments, alongside establishing robust ethical frameworks and professional development programs.

The study underscores the necessity for additional empirical research to validate these strategies and to refine the interplay between technology, instructional methods, and policy-making. In summary, while AI offers promising avenues for enriching programming education, its long-term success depends on an integrated, multi-faceted strategy that aligns technological innovation with sound pedagogical practices and ethical oversight.

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The Impact of Game-based Technologies on the Development of Attention in Younger School-age Children

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Abstract—The article theoretically substantiates, develops, and experimentally verifies the effectiveness of an authorial program for implementing game-based technologies in physical education lessons for younger school-age children to enhance attention properties. Under experimental conditions, positive changes were observed in the dynamics of the experimental group of younger schoolchildren regarding attention properties, particularly productivity, stability, span, concentration, and shifting. The research aim is to determine the effectiveness of implementing game-based technologies in the physical education process of younger school-age children. **Organization and Methods.** The study examined the level of attention properties, including productivity, stability, span, concentration, shifting, and experimentally verified the effectiveness of a program integrating game-based technologies into the physical education process of younger school-age children. A total of 47 schoolchildren participated in the study (24 girls and 23 boys). Research methods included literature analysis, psychodiagnostic methods (Tests Landolt rings), pedagogical experiment, and mathematical statistics. **Results.** A program for implementing game-based technologies in physical education lessons for younger school-age children was presented and scientifically substantiated. The program included the application of game-based technologies in physical education through a comprehensive combination of sports and movement games, entertainment

activities, digital multimedia applications (such as BetterMe, Active Arcade), storyline scenarios, game creativity, play-based gymnastics, and relaxation exercises aimed at developing students' attention. **Conclusions.** The developed program was implemented in the educational process, and its effectiveness was confirmed. The research results demonstrated its positive impact on attention properties, particularly productivity, stability, span, concentration, and shifting in younger school-age children, as confirmed by mathematical statistics.

Keywords—game-based technologies, physical education, younger school-age children.

I. INTRODUCTION

In the modern development of education, the issue of forming cognitive functions in younger school-age children is gaining particular attention, driven by the need to ensure a high level of learning activity and intellectual development of students [1]. One of the key characteristics of cognitive activity that directly affects academic success is attention. It plays a crucial role in the processes of perception, analysis, comprehension, and assimilation of information. A high level of attention development ensures the effective completion of educational tasks, contributes to the formation of self-control and reflection

Online ISSN 2256-070X

<https://doi.org/10.17770/etr2025vol3.8526>

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skills, and is also a necessary condition for the development of other cognitive processes, such as memory, thinking, and speech [2].

At the same time, attention in younger school-age children is characterized by relative instability, which manifests in rapid fatigue, distraction by external stimuli, and insufficient ability to maintain prolonged focus on a single activity [3]. This fact necessitates the search for effective pedagogical methods aimed at stimulating and developing attention as one of the fundamental cognitive functions. Modern research in the fields of pedagogy, psychology, and physical education indicates that one of the most effective means of enhancing children's cognitive activity is the integration of game-based technologies into the educational process of general education institutions. These technologies best align with children's age-related characteristics, promote natural engagement in the learning process, and create a comfortable educational environment that fosters motivation for cognitive activity [4], [5], [6], [7].

Game-based technologies are widely used in educational practice due to their dynamism, emotional engagement, and interactivity. Their implementation promotes the development of various aspects of attention, such as productivity, stability, distribution, and shifting [8], [9]. Recent studies indicate a significant impact of game-based technologies on the attention development of younger school-age children. In particular, the use of didactic games in the learning process enhances students' cognitive interest and concentration. Nikolyachuk [14] notes that didactic games serve functions such as knowledge reinforcement, increased interest, attention concentration, and the formation of volitional qualities in younger students.

Additionally, Panchenko's [15] research emphasizes that game-based technologies foster the development of students' creative abilities, which are closely linked to their ability to focus attention and generate original ideas. The use of role-playing and didactic games creates conditions for active student engagement in the learning process, positively influencing their attention and creativity.

At the same time, Holubyuk's [16] study highlights the positive impact of game-based technologies on the cognitive activity of children with special educational needs. The incorporation of games in the education of such students contributes to improvements in their attention, memory, and overall cognitive activity.

Interactive games, augmented reality, and gamification have proven effective in enhancing students' coordination skills, attention, and endurance. Specifically, researchers [17], [18], [19] note that digital game-based technologies, such as mobile applications and virtual simulations, facilitate the individualization of the learning process and the adaptation of physical exercises to students' fitness levels.

However, studies emphasize the necessity of a balanced combination of traditional teaching methods with game-based technologies to maximize their effectiveness in developing students' physical qualities.

It is also important to consider that not all game-based technologies are equally beneficial. Some studies highlight the advantages of traditional games without multimedia technology. For instance, a study [20] conducted by AIJU in collaboration with the Complutense University and the Crecer Jugando Foundation found that 76% of primary school students feel more creative when playing without digital devices, and 61% report improved social skills through physical or board games.

The relevance of this research is driven by the need to implement innovative approaches to developing attention in younger school-age children, as well as the high potential of game-based technologies as an effective means of shaping and enhancing their cognitive functions.

The research aim is to determine the effectiveness of implementing game-based technologies in the physical education process of younger school-age children.

II. MATERIALS AND METHODS

The study was conducted during the 2023–2024 period. It examined attention indicators in children aged 9–10 years (younger school-age students), specifically assessing characteristics such as productivity, stability, span, concentration, and shifting. The effectiveness of applying game-based technologies in physical education was experimentally tested. The study sample included 47 students. The pedagogical experiment was conducted with younger school-age students (4th grade) who, based on their health status, were classified into the main educational group. Physical education lessons were conducted by a properly trained teacher with professional qualifications.

Data collection and processing were carried out in accordance with the Helsinki Declaration of the World Medical Association, which regulates ethical principles for conducting medical research involving human participants. All participants were informed about the measurement procedures, and parents provided written consent for data processing and permission for the use of their children's indicators in further scientific research.

To achieve the study's objective, the following research methods were used:

- Literature analysis was employed to examine the prerequisites for increasing the effectiveness of physical education lessons through the use of game-based technologies in the physical education of younger school-age children, as well as to analyze theoretical foundations for attention development in younger students.

- Psychodiagnostic methods (Tests Landolt rings) were applied to assess attention characteristics, including productivity, stability, span, concentration, and shifting [21]. The Landolt ring test was conducted using specialized sheets containing a random set of rings with openings oriented in different directions. The participant scanned the row and crossed out specific rings as indicated in the instructions. The assessment was based on a quantitative analysis of the reviewed (crossed-out) and missed (uncrossed) symbols, as well as the time taken to complete a specified number of rows. To enhance the objectivity of the analysis, specialized formulas were used to determine the levels of productivity, stability, span, concentration, and shifting of attention. Measurements were conducted in the first half of the day, before the start of school lessons, and results were recorded in protocols.
- A pedagogical experiment was conducted to test the effectiveness of the author's program involving game-based technologies in the physical education of younger school-age children.
- Mathematical statistics methods were applied to analyze the research data using the STATISTICA 8.0 software (Statsoft, USA). The results were presented as mean values and standard deviations. Statistical significance was set at $p < 0.05$ [22].

III. RESULTS AND DISCUSSION

Game-based technologies, due to their clear structure, didactic orientation, and integration of innovative approaches, are an effective tool for optimizing the educational process for younger school-age children. They involve the systematic use of specially designed game techniques, methodological approaches, and digital resources, ensuring a comprehensive impact on the development of cognitive abilities, physical qualities, psycho-emotional state, and social skills of students. Additionally, game-based technologies enhance motivation for physical activity, create a comfortable educational environment, and expand opportunities for individualized learning.

We have developed an original program incorporating game-based technologies for younger school-age children, aimed at improving attention levels, particularly in terms of productivity, stability, span, concentration, and shifting. The pedagogical experiment was conducted during the 2023–2024 period. The study sample consisted of 24 students (12 girls and 12 boys) in the control group (CG) and 23 students (8 girls and 15 boys) in the experimental group (EG).

Students in the EG followed the proposed program three times a week for 45 minutes, in accordance with the

school schedule. Students in the CG followed the traditional physical education program.

The program was designed for a duration of three months (36 lessons) and was divided into two stages: the preparatory stage (10 lessons) and the main stage (26 lessons). The objectives of the preparatory stage were: to familiarize children with the rules for the safe use of game-based and digital technologies to enhance physical activity; to teach the basics of working with digital applications; and to introduce game rules and fundamental motor actions. The objective of the main stage was to improve students' attention characteristics through the integration of game-based technologies into physical education lessons.

The original program integrating game-based technologies in the physical education of younger school-age children included a set of integrated methods, namely:

- *the role-playing method*, where students assumed the roles of characters and performed tasks according to a specific storyline;
- *the game modeling method*, which involved creating situations requiring students to react quickly to changing conditions;
- *the action alternation method*, which introduced games with frequent task changes into physical education lessons;
- *the reflective inclusion method*, where students analyzed and assessed their task performance upon completion of game-based activities;
- *the obstacles and challenges method*, where students performed tasks requiring them to track multiple moving objects simultaneously or adjust their actions in response to external stimuli.

The program structure included three main modules: the cognitive-game module, the motor-game module, and the digital-game module. The *cognitive-game module* involved tasks that stimulated thinking activity during motor actions (e.g., games for recognizing signals, combining movements according to specific algorithms) as well as reflective exercises aimed at analyzing completed tasks, recognizing personal achievements and difficulties, and fostering motivation for further physical activity. The *motor-game module* included dynamic exercises utilizing game modeling, allowing students to develop concentration skills under conditions of increased physical activity. Examples included: the "Maze" game, where students navigated a route while responding to unexpected teacher signals (e.g., changing direction or mode of movement); the "Traffic Light" game, in which children modified their movements based on color or sound signals; team relay races with variable conditions, requiring students to quickly adapt their strategies, add

new movement elements, and respond to changing tasks. The *digital-game module* incorporated well-known sports-related digital applications, such as BetterMe and Active Arcade, which feature interactive game-based exercises, team games, dance-based video exercises with elements of novelty, and competitive elements [23], [24], [25]. These features made the sessions engaging and interactive for students.

Each lesson followed a traditional structure, consisting of preparatory, main, and concluding parts:

- the preparatory part implemented the cognitive-game module through physical exercises and games that stimulated thinking activity, as well as general developmental exercises to prepare students' bodies for upcoming physical exertion;
- the main part combined the motor-game module (exercises and games using game modeling, role-playing games, relay races, and team-based tasks) and the digital-game module;
- the concluding part involved the reapplication of the cognitive-game module through reflective exercises to summarize the lesson, analyze completed tasks, and discuss achieved results.

During program implementation, strict adherence to safety regulations and proper preparation of the physical education space was maintained.

The implementation of game-based technologies in the program was based on the principles of activity, awareness, adaptability, variability, and a motivational approach, which allowed for a differentiated approach to students of varying skill levels and created favorable conditions for the development of their cognitive abilities [26], [27], [28].

During the experiment, the impact of the proposed program on improving attention indicators in children aged 9–10 was assessed, particularly in terms of productivity, stability, span, concentration and shifting. A general evaluation of the results of the formative experiment was conducted, and the reliability of the obtained data was determined. The analysis of the study results showed that at the beginning of the experiment, there were no statistically significant differences in attention indicators between the control group (CG) and the experimental group (EG). This confirms that both groups were homogeneous in terms of their initial attention levels.

An analysis of attention characteristics in 9–10-year-old children and their changes throughout the experiment indicated positive improvements in several attention indicators due to the implementation of game-based technologies in physical education lessons (Table 1).

The study of attention productivity made it possible to assess children's ability to effectively concentrate on tasks, maintain attention over a prolonged period, switch quickly between different activities, and process information with minimal errors. In the Landolt Ring Test, attention productivity is evaluated using an accuracy coefficient (the ratio of correctly identified symbols to the total number of viewed symbols), where: high level: 0.9–1.0 arbitrary units; medium level: 0.8–0.89 arbitrary units; reduced attention productivity: <0.8 arbitrary units. The measurement is conducted in arbitrary units, allowing for a quantitative assessment of attention productivity. A higher level is characterized by a greater number of correctly identified symbols with a minimal number of omissions and errors.

The results of the study showed that, within the pedagogical experiment, the attention productivity indicator in EG students increased by 0.05 ± 0.02 arbitrary units, which represents a statistically significant improvement ($t=2.644$; $p<0.05$). As a result, their attention productivity level increased from medium to high. In contrast, CG students showed only a slight improvement of 0.01 ± 0.03 arbitrary units, which did not reach statistical significance ($t=1.516$; $p>0.05$), indicating that their attention productivity remained within the medium level.

The statistically significant improvement in attention productivity in the EG was attributed to the purposeful integration of game-based technologies into physical education lessons. Specifically, the combination of motor activity with cognitive tasks, which required rapid situation analysis and decision-making, played a key role in enhancing information processing efficiency.

TABLE 1. INDICATORS OF ATTENTION CHARACTERISTICS IN STUDENTS OF EXPERIMENTAL AND CONTROL CLASSES

Indicators	before the experiment		after the experiment		p
	CG	EG	CG	EG	
	$\bar{x} \pm Sx^-$	$\bar{x} \pm Sx^-$	$\bar{x} \pm Sx^-$	$\bar{x} \pm Sx^-$	
attention productivity, arbitrary units	0,86 ± 0,03	0,85 ± 0,02	0,87 ± 0,03	0,90 ± 0,02	$p<0,05$
attention stability, arbitrary units	0,76 ± 0,02	0,79 ± 0,03	0,78 ± 0,02	0,91 ± 0,03	$p<0,05$
attention span, symbols/min	74,0 ± 0,32	69,7 ± 1,38	74,7 ± 0,32	80,3 ± 2,59	$p<0,001$
attention concentration, %	86,8 ± 0,56	85,9 ± 0,62	88,3 ± 0,75	90,2 ± 0,86	$p<0,001$
attention shifting, %	6,9 ± 0,25	7,5 ± 0,27	7,4 ± 0,22	8,2 ± 0,26	$p<0,05$

During the experiment, positive changes were observed in the indicators of attention stability, which characterize the ability to sustain attention for a prolonged

period and efficiently process information without a decline in performance among younger school-aged children. Attention stability in the Landolt test is assessed by analyzing changes in performance throughout the entire testing process. The standard interpretation of this indicator is based on comparing task performance efficiency at different stages of testing (beginning, middle, end). A decrease in the number of correctly identified symbols or an increase in the number of omissions and errors in the later stages of testing indicates a decline in attention stability, whereas stable or improved results suggest a high level of attention stability throughout the task. Attention stability is evaluated using the stability coefficient (K_s), which is calculated as the ratio of attention performance at the final stage of testing to the initial stage and is interpreted as follows: a K_s value ≥ 1.0 arbitrary units indicates high attention stability, characterized by consistent or improved performance throughout testing; $K_s=0.8-0.99$ arbitrary units suggests a moderate level of attention stability, where a slight decrease in performance is observed, potentially indicating mild fatigue; $K_s<0.8$ arbitrary units signifies reduced attention stability, manifested in a significant decline in performance, rapid depletion of cognitive resources, reduced concentration, and difficulty maintaining attention throughout the test.

The analysis of attention stability research results demonstrated a statistically significant improvement in the experimental group (EG) children ($t=2.314$; $p<0.05$), reflected in an increase of this indicator by 0.12 ± 0.03 arbitrary units and a simultaneous change in the level of attention stability development from low to moderate. At the same time, positive changes were also recorded in the control group (CG) children; however, their increase was only 0.02 ± 0.02 arbitrary units, and the obtained results were not statistically significant ($t=1.038$; $p>0.05$), indicating the retention of a low level of attention stability.

This statistically significant increase in attention stability indicators among EG children can be explained by a combination of two key factors. First, the application of various game exercises and role-playing games contributed to the development of attention stability by requiring simultaneous control of multiple objects, distribution of attention across different tasks, and maintaining focus in a dynamically changing game environment. Second, the use of diverse game-based tasks helped reduce fatigue, ensuring prolonged concentration in children. Additionally, competitive elements integrated into game-based technologies enhanced children's intrinsic motivation and encouraged them to achieve better results.

Under experimental conditions, changes were also observed in the indicators of children's attention span, which characterizes the ability to simultaneously perceive, retain, and process information without a decline in task performance quality. This parameter is assessed using the

Landolt test based on the total number of correctly processed symbols per unit of time. A high level corresponds to more than 80 symbols per minute, a medium level ranges from 60 to 79 symbols per minute, and a low level is defined as fewer than 59 symbols per minute.

Children in the experimental group (EG) demonstrated a statistically significant increase in attention span ($t=4.41$; $p<0.001$), reflected in an increase in this indicator from 69.7 ± 1.38 symbols/min to 80.3 ± 2.59 symbols/min throughout the experiment. A shift from a medium to a high level of attention span was also noted. Meanwhile, no significant changes were recorded in the control group (CG) ($t=1.89$; $p>0.05$). This statistically significant improvement in attention span indicators under the influence of the author's methodology can be explained by the use of the "obstacles and challenges" and "game modeling" methods, as their application requires the simultaneous perception and control of multiple objects, as well as the execution of multiple tasks under variable conditions.

Positive shifts were also observed in EG children regarding attention concentration, which characterizes the ability to maintain prolonged and high-quality focus on a specific activity over a certain period. In the Landolt test, attention concentration is assessed as a percentage (%) and is determined as the ratio of correctly completed tasks to the total number of processed symbols, allowing for the identification of the proportion of successfully completed tasks relative to the total workload. The level of attention concentration is classified as very high at $\geq 95\%$, high within the range of 90–94%, medium from 80% to 89%, below average from 70% to 79%, and low at $<70\%$.

The study revealed a significant increase in attention concentration scores among EG students, rising from $85.9\pm0.62\%$ to $90.2\pm0.86\%$ ($t=4.82$; $p<0.001$). Additionally, EG children experienced a shift in attention concentration level from medium to high, whereas CG children remained within the medium range. The improvement in EG results can be attributed to the use of various game-based exercises in physical education lessons, which stimulated cognitive mechanisms, particularly attention concentration, in dynamic situations. Regular goal orientation and task execution monitoring contributed to the development of the ability to maintain prolonged and effective focus on key aspects of activity.

As a result of the influence of the experimental program, statistically significant changes were also observed in the indicators of attention shifting among children in the experimental group (EG). Attention shifting characterizes the ability to quickly and effectively change focus from one object or activity to another without a decrease in performance, determining cognitive flexibility and adaptability to changing conditions. In the Landolt test, the attention shifting indicator is defined as

the ratio of the difference between the task execution time under standard conditions and the time required to complete the task after modifying the conditions to the total task execution time.

The level of attention shifting is categorized as follows: a high level (>12–15%) indicates rapid responsiveness and high cognitive plasticity; a medium level (6–12%) reflects sufficient adaptability and normal efficiency of shifting; and a low level (<6%) suggests slow shifting and difficulties in adapting to new conditions. The use of percentage-based evaluation in the Landolt test is necessary to normalize results and make them comparable across different participants. The percentage value represents the relative change in task execution time after altering the conditions in relation to the initial time, allowing for an objective assessment of cognitive flexibility regardless of individual differences in processing speed.

Among EG children, the attention shifting indicator before the experiment was $7.5 \pm 0.27\%$, increasing to $8.2 \pm 0.26\%$ after its completion ($t=2.276$; $p<0.05$), indicating statistically significant changes. However, despite the statistical significance, the development level of this ability remained within the medium range throughout the study. In CG children, improvements in the attention shifting indicator were also observed, increasing from $6.9 \pm 0.25\%$ before the experiment to $7.4 \pm 0.22\%$ after ($t=1.866$; $p>0.05$), but these changes were not statistically significant.

This outcome is attributed to the incorporation of a large number of game-based exercises in EG physical education lessons that involved sudden rule changes, requiring rapid attention shifts depending on new conditions. Additionally, team games necessitated constant attention shifts between the ball, opponents, and teammates; relay races enhanced the ability to respond quickly to new tasks; and games with tactical elements promoted quick transitions between situation analysis and decision-making.

Thus, it can be concluded that the developed program, incorporating game-based technologies into the physical education process for younger school-age children, is effective and can be applied to improve attention indicators.

IV. CONCLUSIONS

Game-based technologies are an effective tool in physical education, contributing not only to the development of physical qualities but also to significant improvements in cognitive functions, particularly attention. Changes in game conditions, the need for constant attention shifting between different tasks and objects, and the requirement for rapid adaptation to new situations activate mechanisms of attention distribution

and concentration. The dynamic nature of game-based activities encourages children to maintain focus for extended periods, enhancing their ability to effectively manage attention under changing informational demands. Thus, integrating game-based technologies into physical education not only improves children's physical condition but also fosters the development of stable and well-developed attention, which is a crucial component of their overall cognitive development.

The developed program for implementing game-based technologies in the physical education of younger school-age children aimed to improve students' attention levels, particularly in aspects such as efficiency, stability, span, concentration, and shifting. The program included three main modules: cognitive-game, motor-game, and digital-game, each designed to develop different characteristics of students' attention. The cognitive-game module stimulated thinking activity and motivation through games and reflections. The motor-game module enhanced focus and adaptability through dynamic exercises and varied game tasks. The digital-game module utilized interactive sports applications such as BetterMe and Active Arcade, making the sessions more engaging and interactive.

The author's program, which integrated various game-based methods (narrative-role-playing, game modeling, action alternation, reflexive inclusion, obstacles and challenges), facilitated the development of students' attention characteristics by engaging them in tasks requiring rapid action changes and result evaluation. The sessions were divided into two stages: a preparatory stage, focused on familiarization with the basics of safe use of game-based and digital technologies, and a main stage, aimed at developing attention through the integration of diverse game-based methods. Each session followed a traditional structure, consisting of a preparatory, main, and concluding part.

It was found that during the pedagogical experiment involving the implementation of the game-based technology program, more pronounced positive changes were observed in the indicators of EG children compared to CG children.

Analysis of the results demonstrated that during the experiment, a positive impact on the attention indicators of EG children was confirmed, specifically:

an improvement in attention productivity by 0.05 ± 0.02 arbitrary units ($t=2.644$; $p<0.05$), with a transition from medium to high development level; an increase in attention stability by 0.12 ± 0.03 arbitrary units ($t=2.314$; $p<0.05$), with a shift from low to medium development level; an enhancement in attention span by 10.6 ± 1.21 symbols per minute ($t=4.41$; $p<0.001$), raising the development level from medium to high; an improvement in attention concentration by $4.3 \pm 0.62\%$ ($t=4.82$; $p<0.001$), transitioning from medium to high

level; and an increase in attention shifting by $0.7 \pm 0.26\%$ ($t=2.276$; $p < 0.05$).

Thus, the above research findings confirm the effectiveness of the author's program using game-based technologies, which can be recommended for enhancing the attention development of younger school-age children.

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Gamification Methods for Developing Lexical Competence of Engineering Students

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Abstract—In the contemporary world, where information technology finds application in all spheres of life, the issue of the effectiveness of teaching a foreign language to future engineers emerges as a particularly significant one. It has been noted that traditional teaching methods tend to demonstrate a lack of sufficient effectiveness in the development of lexical competence in future specialists, thus giving rise to a significant need for the exploration of innovative, new approaches to be developed. One such approach that has been identified is gamification, which involves the integration of game elements into the learning process. The purpose of the research is to analyse the peculiarities of using gamified learning technology in the formation of future engineers' lexical competence and to develop practical recommendations for its implementation of game methods in the process of studying the discipline "Foreign Language (English) for Specific Purposes". The study used a complex of methods, in which theoretical analysis of scientific literature on gamification and lexical competence development, student interviews, pedagogical monitoring of the learning process and an

experimental study of the effectiveness of gamified learning materials were used. As a result, the theoretical basis for the use of gamification methods in the formation of future specialists' lexical competence has been determined. It has been found that gamification helps to increase students' motivation to learn, activate their cognitive activity, develop independence and responsibility. The article provides specific examples of game-based teaching methods for the formation of lexical competence, which includes the following components: game goal, competition elements, virtual reality, and interactive tasks. The study results have confirmed the effectiveness of the developed methodology in the educational process. It has been found that students who studied using gamified learning materials demonstrate a significantly higher level of lexical competence than those who studied using traditional methods. As a conclusion, the authors emphasise that gamification contributes to the development of an interesting and motivating learning environment, which positively affects the acquisition of lexical material.

Online ISSN 2256-070X

<https://doi.org/10.17770/etr2025vol3.8543>

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Keywords—*Activation of cognitive activity, game elements, gamification, interactive tasks, lexical competence, student-centred approach, training of future engineers.*

I. INTRODUCTION

The contemporary world is characterised by the active development of international relations in all areas, including engineering and manufacturing, and as a result, engineers must constantly update their knowledge and skills to be competitive. Most of the current scientific and technical publications, patents, standards and other documents are published in English. Therefore, English language proficiency is essential to obtain access to the latest information and technologies. English is the language of international communication in the scientific and technical fields and is the key to successful communication and cooperation with international partners.

International employers increasingly value engineers who speak English, and companies operating in the international market are demanding a high level of English proficiency from their employees. Therefore, the development of English professional vocabulary competence is an important factor in the successful employment and career development of engineers. Taking all these factors into consideration, the formation of English professional lexical competence is a relevant and crucial task for the training of modern engineers who will work successfully in the context of globalization and international integration. In the process of training prospective specialists, the discipline “English for Specific Purposes” (ESP) is a fundamental component that contributes to the acquisition of professional terminology, the formation of communication skills, adaptability, and the development of a behaviour culture in a professional environment. While traditional teaching methods are often not effective enough to develop the lexical competence of future specialists, it is necessary to find new, innovative approaches. Among these approaches is gamification, which involves the use of game elements in the learning process.

The development of prospective engineering specialists’ lexical competence is a highly significant issue in many types of research. The problem of developing prospective engineers’ professional English lexical competence is of considerable importance and covers various aspects, namely: identifying the components of professional English lexical competence, analysing modern methods and technologies of teaching engineering students, developing and implementing effective models of developing future engineers’ professional English lexical competence.

The lexical competence of future engineers is a fundamental aspect of their professional training in today’s globalised world. English language skills not only provide students with access to the latest scientific and technical developments, but also facilitate effective international collaboration, knowledge, and technology

exchange. As one of the most dynamic and innovative industries, engineering requires professionals to constantly update their knowledge, which often involves working with English-language sources: scientific articles, technical documentation, patents, standards, and other materials.

The development of future engineers’ English lexical competence involves not only mastering basic vocabulary but also mastering specialized terminology used in specific engineering disciplines. This requires students to be able to distinguish and use different styles of speech, understand contextual nuances, and communicate effectively in a professional environment. Particular attention should be paid to the development of receptive skills, such as reading and listening, as they are the basis for receiving and processing information from English-language sources.

Authentic resources such as scientific journals, technical reports, video lectures, and webinars should be used in the learning process, allowing students to become familiar with the real-world use of English in an engineering context. An important aspect is also the development of productive skills such as writing and speaking, which allows students to effectively present their ideas and work in English. This may include participating in international conferences, publishing scientific articles, and preparing technical reports and presentations.

Research Objective: to investigate the effectiveness of gamification in the formation of future engineers’ lexical competence.

The formation of future engineers’ English lexical competence is a permanent process that requires constant self-improvement and updating of knowledge. Students should be motivated to learn English independently and use it in their professional activities. It is also important to create a favourable learning environment that promotes the development of language skills and encourages students to actively use English.

Peters and Fernandez [1] revealed the problem of students’ need to find English-language terms during their professional training. In the study, the authors emphasised the statement that students learning a foreign language for professional use still require the creation of conditions that simulate a professional environment, which includes professional documentation, professional discourse, and the atmosphere of the workplace. The authors provided a direct impact on the students’ profession and their involvement in foreign language terminology. According to Masrai [2], lexical competence, in addition to single terms, includes a system of phrases of this term, which are also important in the process of forming lexical competence. Tyne, Smovzhenko and others [3], [4] analysed scientific research on the introduction of new methods in the context of developing the lexical competence of future specialists in order to form communication skills in a professional environment in the context of students’ knowledge and, as a result, to apply a

differentiated approach in the process of forming professional lexical competence.

The process of developing future engineers' lexical competence includes knowledge of lexical units, idioms, phrase unities, and abbreviations that will be used in the professional field in the future. According to Bakirova [5], the skills that prospective engineers should master are the following: understanding the meaning of lexical units and aspects of their use in a professional context, interpreting professional information, and being able to actively apply the acquired knowledge in the process of professional communication. Therefore, in the ESP course, students should be involved in tasks related to defining and understanding the meaning of professional terms, memorising and using the terms correctly in a professional context. Usually, such tasks are previously performed in accordance with the textbook [2].

Modern scholars emphasise the potential of using game-based learning methods in the professional training of specialists at universities. The application of this method is highlighted in the scientific papers of Milosz and Milosz [6], who argued in the study that the use of gamified learning in engineering education is constantly increasing. This statement is continued in the scientific article by Irwanto and others [7], who indicated that gamification is important in supporting educational goals. Through the analysis of many sources, the effectiveness of this method was proved by the results of monitoring the performance of students in higher education institutions [8]–[9]. A research study by Khaldi and others [10] was devoted to a comprehensive analysis of using gamified methods in online learning. In this case, gamification is considered as a teaching method for the development of essential competencies. The study of Dmitrenko and others [11] presented how learning lexical games with the elements of social-emotional learning can be used in the formative assessment of prospective specialists.

Recent research by Madero-Gonsales et al. [16] demonstrates the significant impact of gamification on meaningful learning and student performance specifically in online engineering courses, highlighting its relevance to technical education contexts. Additionally, Soni and Banwet [17] further support these findings, showing that gamification significantly enhances learning outcomes by improving student attendance and engagement in classroom tasks. Their study emphasizes the importance of implementing gamification in management education policy. Jun and Lucas [18] provide a comprehensive review of various gamification elements and their specific impacts on educational settings, identifying key components that drive successful implementation.

The impact of gamification on the development of students' professional competencies is an urgent issue that still needs to be studied. Most researchers emphasize the extraordinary effect of this method; in particular, Jenner and Arudhas [12] noted that gaming technologies increase students' confidence and develop their social skills. The authors emphasised the effectiveness of bridging

knowledge gaps and improving the overall level of language proficiency.

In an empirical study, Alsadoon [19] demonstrates concrete evidence of gamification's positive impact on student motivation, showing measurable improvements in engagement metrics. Similarly, Hellin et al. [20] found that creating gamified learning environments not only enhances student motivation but also contributes to educational sustainability by creating more enduring learning experiences.

A positive aspect is also the motivation to engage students in learning activities, as the game form of learning creates a positive emotional atmosphere that affects the acquisition of lexical units. Performing learning tasks in a game format activates their creativity and critical thinking. The interaction of all participants in the learning process contributes to developing their communication skills in artificially created professional situations, where students actively exchange information and argue their points of view [8], [9].

In the psychological context, gamified learning helps to reduce the language barrier, which is a negative trend for future professionals. The game form of activity allows students overcome psychological barriers and reduces stress and tension. The enormous potential of gaming technologies can be seen in activating motivation to learn. Game elements, such as points, rewards, and competitions, contribute to the production of dopamine, a neurotransmitter associated with feelings of pleasure and motivation. It creates positive feedback that encourages participants in the educational process to achieve learning goals. In addition, gamification supports basic human psychological needs, namely the need for communicative competence and autonomy, which contributes to the formation of independent learning.

Game tasks enhance problem-solving and conflict-resolution skills, promote critical thinking, and allow you to experience different emotions and learn to manage them. In addition to the above, game-based learning methods contribute to the development of empathy and professional communication skills [13]–[14]. Another positive impact of such technologies is the reflective effect, where participants can independently assess their strengths and mistakes and analyse their learning dynamics. Gamified learning techniques help to overcome the fear of mistakes and failures because in traditional learning, mistakes are often perceived as negative phenomena that lead to anxiety.

In the educational environment with elements of gamified learning, mistakes are considered as part of the learning process, which provides an opportunity for feedback and improvement. Games often provide an opportunity to repeat a task or try a different approach, which allows students to feel more confident and contributes to the formation of a positive attitude and self-esteem [15]. Accordingly, the authors confirm the positive impact of game-based learning methods and consider it

appropriate to use gamification in the process of developing lexical competence.

Thus, the research reviewed demonstrates a substantial effect of using the gamification method during university studies. Still, the potential of this method has not yet been explored in many aspects of students' professional training.

II. MATERIALS AND METHODS

To accomplish this goal, the authors used theoretical methods, in particular, the analysis of scientific research on linguistics, pedagogy, and methods of teaching foreign languages and the process of synthesis and generalisation of the information obtained.

The qualitative research was conducted at two universities: Berdyansk State Pedagogical University, which was relocated from Berdyansk to Zaporizhzhia due to Russia's full-scale invasion and the beginning of the war, and Mykhailo Kotsiubynskyi Vinnytsia Pedagogical University. A total of 38 students participated in the study: 14 students from the Faculty of Mathematics, Physics and Computer Sciences at Mykhailo Kotsiubynskyi Vinnytsia Pedagogical University and 24 students from Berdiansk State Pedagogical University's Faculty of Physical, Mathematical and Technological Education, distributed across three groups: 9 students from Computer Science, 8 from Mathematics and Physics, and 7 from Technology Education. The gender distribution included 29 male participants (9 from Vinnytsia and 20 from Berdiansk) and 9 female participants (5 from Vinnytsia and 4 from Berdiansk).

In accordance with the aims of the study, the authors used the method of questioning students to determine the level of their professional lexical competence and the degree of satisfaction with teaching methods in the course of studying the ESP discipline. In the process of applying the monitoring and testing method, the authors determined the effectiveness of the gamification method in the acquisition of professional-oriented vocabulary by future engineers.

The crisis conditions caused by the war and the psychological state of the students prompted this research, as the instructors decided to implement Gamification Methods for Developing Lexical Competence of Engineering Students. The game-based approach was chosen as an effective tool to increase motivation and engage students in the learning process under challenging psychological circumstances. Understanding that prolonged stress significantly impairs learning capacity, the instructors sought to compassionately evaluate the effectiveness of the gamification approach by first examining the students' own impressions. Students were asked to respond to the key question: "To what extent has the implementation of game-based activities improved your ability to learn, retain, and apply professional engineering terminology in English compared to traditional learning methods?"

At the beginning of the study, the authors conducted a survey of engineering students from both universities regarding their confidence in the ESP learning process and determined their level of academic achievement in professionally oriented lexical vocabulary. As a result, the authors identified that among the difficulties students face when studying the ESP discipline is a large number of terms that participants in the educational process find difficult to learn, understand, and remember, which makes it challenging for them to be active participants in the professional environment.

In the first semester, students completed lexical tests at the conclusion of the modules in order to learn the number of new terms learned on a particular topic. The results showed that, overall, students learnt about 55% of the new professional terms. Moreover, if the term was a passive vocabulary term and not related to the students' future profession, almost 90% of the students demonstrated ignorance of it.

In the second semester of the first year, students were offered a gamified methodology aimed at quantitative and qualitative learning of new professional terminology based on the use of gamification.

The study included first- and second-year students enrolled at the Faculty of Physical, Mathematical and Technological Education of Berdyansk State Pedagogical University and the Faculty of Mathematics, Physics and Computer Sciences at Mykhailo Kotsiubynskyi Vinnytsia Pedagogical University.

To test the effectiveness of the proposed gamification methodology, game-based methods were implemented in the educational process of studying ESP by engineering students at both universities during one semester. At the end of the study, the authors conducted a final survey in order to observe the impact of game-based tasks on engineering students' lexical competence. The survey results indicated that 82% of students from both universities reported significant improvement in their ability to learn and retain specialized terminology when using gamified approaches, with the highest satisfaction rates observed among the displaced students from Berdiansk (87%). Students were informed about the study objectives and participated in the study voluntarily.

III. RESULTS AND DISCUSSION

In the course of testing the hypothesis, the authors applied the gamification methods in the ESP classroom that, in the authors' opinion, will contribute to the development of future engineers' professional lexical competence. In the authors' experience, to achieve this goal, the key component is the knowledge of future engineers in the area of professionally oriented vocabulary, its semantic features, synonymous and antonymic aspects. In particular, students need to learn how to identify lexical items in a text or spoken language, establish links between them, and interpret the content of professionally oriented texts.

To accomplish this objective, the authors consider semanticisation (tasks aimed at clarifying the meaning of professional lexical items, dictionary search, contextual guessing), memorisation (tasks aimed at creating associations with lexical items, visualisation of professional terms) and the use of lexical items in the process of communication to be a successful strategy.

In addition, an essential aspect is the development of student's ability to use lexical material in a specific situation of professional communication, to communicate in professional monologues, and to prepare reports and presentations on professional topics using professional vocabulary. In the process of training a highly competitive specialist, the authors also considered it an urgent task to teach students to participate in discussions, defend their point of view and be able to argue it using the necessary vocabulary and structures.

The implementation of the gamification method in vocabulary learning (for professional purposes) has great relevance, as game elements encourage students to learn new vocabulary and have an interactive activity. Consider some examples of game-based methods that can be used to teach English professional terms. According to the results of the research of Madero-Gonsales and others [16], there are arguments to consider the method of 'Technical Vocabulary' effective, where students are asked to explain the term they receive on the card. The participants of the game can be asked to match the objects displayed in the pictures, which are made of the specific material, with a card with the name of the material in letters (steel, glass, aluminium, copper, rubber), or to define the description of the following characteristics (water-resistant, elastic, lightweight, corrosion-resistant, heavy, durable). Such activities can be organised in groups or pairs where students can help each other.

In developing the knowledge of professional terms, the game 'Technical Scrabble' is used to help students to form the names of professional words from letters (e.g. surface, suspension, friction, hacksaw, reliability, manufacturing).

A similar method is the game 'Engineering Word Associations', which is aimed at forming an associative series of words (for example, socket, wireless, circuit, scratch). Students have to find as many associations as possible to specific professional terms. In the process of completing such tasks, students develop critical thinking, consolidate the material they have learned, and learn new words.

To revise the terms, students can play a game with cards called 'Professional cards', where the aim is to score more points by guessing the terms. One student shows a card with a photo of a specific professional term, and the others find and show a card with the spelling of the term. In this way, students who have learnt more words and guessed their meanings get more points. In addition to this format, students can also perform tasks to find synonyms or antonyms, where the task is to find the opposite term to the concept depicted or its synonym. Students can use

professional English dictionaries or online applications to complete their assignments. It is crucial to emphasise the unique atmosphere of completing such tasks in a group setting, as all participants are involved in the task, and the team members help each other, consult together, argue, and defend their points of view.

To increase professional vocabulary, the game 'Professional Vocabulary' is widely used, which aims to increase the vocabulary of students according to a specific topic being studied. For example, when studying the topic 'Problems of engineering faults', students have the opportunity to find synonyms for the words detected, sufficient, balance, correct, broken, fault, and disconnect, which will be useful in professional communication.

The Engineering Vocabulary Challenge Game. The aim is to memorize professional terms and develop listening skills, significantly increasing active professional vocabulary. The rules of the game are that the presenter says the definition of professional terms (circuit, component, data, equipment, technology, voltage, strain), and the students take turns guessing it. If someone answers correctly, he takes a point. The one who scores the most points is the winner.

As a consequence, the use of such games has a positive impact on the activation of cognitive processes, including memory, attention, and thinking. They have the potential to provide conditions for repeated use and practical application of terms, which provides for their improved understanding and retention in long-term memory, as gamification provides for long-term repetition of vocabulary, which helps to consolidate it in long-term memory. Game features that the authors have used in the implementation of such game elements as repetition with intervals allow students to repeat words and expressions until they are fully mastered. In addition, the formation of associative links between new terms and existing concepts has a positive impact. The use of visualisation, synonyms, and antonyms facilitates the process of memorising new professional terms.

When developing skills in the application of lexical items in a professional environment, tasks involving students in conversations and discussions on professional topics are practical, during which students learn to interpret lexical terms on professional issues to a specific communication situation, express their opinions correctly, and precisely on the subject of discussion, while using different types of speeches (presentation or report). In this context, simulation games are appropriate for use, as they have the potential to simulate real professional communication situations where future engineers can use the professional terms they have learnt.

In order to enhance business and professional communication skills, the authors organised a class with a simulated interview for an engineer position in a company, where one student acted as a director of a certain company and the other was a job applicant. The advantage of this method is that students use the basics of business English and professional terminology. In the

process of such communication, students outline their skills, abilities and experience, which will be useful to them in the future.

For the teamwork, the authors used a game where a team of students represented a particular company and discussed its activities, projects, contracts, and work specifics. The discussions between the companies, which were local government organisations, were quite interesting, as students were involved in solving current issues of public lighting and organising services for community residents. In the process of discussing pressing issues, students presented interesting and effective projects as they foreseen their future.

In this framework, the game 'Future Engineers' was actively implemented, the essence of which was that students acted out specific engineering situations using real English vocabulary, where future engineers presented their projects.

It is worth noting the positive impact of similar simulation games on the development of future engineers' English lexical competence, as students actively use the already learnt specialised vocabulary necessary for their professional activities while simulating real professional scenarios. Games of this type contribute to the comprehension of the contextual meaning of new lexical items and the peculiarities of their specific use in a professional environment, which is extremely relevant for future specialists. Being in an artificially created authentic environment, future specialists feel themselves in professional situations that contribute to the formation of associative links, socialisation, and the activation of the use of professional English vocabulary.

After using lexical learning games in the ESP classes, the authors have concluded that the use of gamification methods in the process of studying the ESP by future engineers has significant potential in the process of forming lexical competence.

The research results obtained after questioning students and analysing their performance results showed that it is easier for students to memorise new professional terms during game activities (96% of students agreed with this statement, as evidenced by the results of the professional vocabulary test).

A significant proportion of students (91%) agreed with the statement that the use of visualisation techniques and repeated repetition of the material significantly improves the memorisation of new words.

All participants of the experimental studying (97%) noted the psychological effect of gamification, namely a positive atmosphere in the classroom, interest, enthusiasm for the learning process, positive, imitation of professional activities, mutual assistance, and lack of stress.

In addition, the authors observed a positive impact on students from teamwork, which is a positive trend, as today in Ukraine, researchers have registered a decrease in the level of social skills of graduates. Gamification in this context has a significant positive effect, as the tasks

required participants to cooperate, share information and interact while organising joint activities in volunteer projects, an active form of citizenship, which activated their social skills and values.

The authors also identified the potential of using gamification in the process of forming engineering students' lexical competence in the activity aspect, namely, improving the participants' skills in developing their spontaneous communication skills. Games with a limited response time or decision-making forced students to react quickly to the situation in an artificially created professional environment, using professional English vocabulary without prior preparation to solve problems (approximately 87% of students noted this characteristic).

The authors received positive responses concerning the ability of future engineers to successfully exchange information, discuss technical details and feel confident during interviews.

96% of the students emphasised that such a positive classroom atmosphere helped them to be confident during presentations, and the developed business communication skills for presentations significantly increased their competitiveness in the engineering labour market.

The survey results agreed with the results of studies [5], [6], [8], [12], [16] that proved the effectiveness of the gamification method for the formation of engineering students' lexical competence. The analysis of relevant studies confirms that gamification helps to increase future engineers' motivation, engagement and efficiency in learning lexical material. The integration of game elements, such as points, levels, competitions and rewards, has been shown to stimulate students' active participation in the learning process, thereby creating a favourable environment for vocabulary acquisition.

IV. CONCLUSION

The results of the present paper explore the use of gamification in the development of lexical competence with a view to investigating the significant potential of this approach in the educational process. The results of the present study confirm that gamification has the potential to make the process of learning vocabulary more interesting and engaging, which is of particular importance for students, as the game-based learning format contributes to better memorisation of vocabulary units, their consolidation, and application in practical situations. Furthermore, individualisation of the learning process is facilitated by gamification, adapting it to the needs and level of knowledge of each student.

However, despite the positive results, there are issues that require further research. It is believed that exploration of the possibilities of using mobile applications, virtual and augmented reality to gamify the vocabulary learning process is necessary. These technologies allow for the creation of interactive and engaging learning environments that can significantly increase the effectiveness of lexical competence development.

Consequently, further research into the use of gamification in the development of lexical competence holds significant potential for developing innovative teaching methods and enhancing educational quality.

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Application of The Educational Information Systems in Professional Training of Agricultural Engineers Studying Physics

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Abstract — The article deals with application of educational information systems in professional training of agricultural engineers studying physics with an emphasis on practice-oriented teaching methods. Physics is a key discipline that ensures the formation of engineering competencies that are necessary for solving problems of an agro-industrial complex. The modern digital technologies make it possible to significantly improve the quality of education, making the learning process more interactive, visual and closer to real professional activity. Particular attention is paid to application of practice-oriented methods, such as professional tests, case methods and digital simulators. Professional tests allow the students to simulate real engineering activities by solving practical problems, related to physical processes in agricultural engineering. The case method promotes the development of analytical and critical thinking, offering the students an opportunity to analyse real situations and engineering problems, followed by a search for optimal solutions. Application of digital simulators makes it possible to model complex physical phenomena and technological processes, conduct virtual experiments and analyse the results, which is especially important in conditions of a limited access to the laboratory equipment. There is an analysis made of the integration efficiency of the educational information systems into the educational process. The obtained results show that the use

of these technologies helps to increase the level of mastering the educational material by 20–30%; it increases the degree of the students' involvement in the educational process and improves the indicators of independent work. In addition, the students develop practical skills, related to the analysis of the engineering problems and the use of digital tools. A conclusion is made that application of practice-oriented methods in combination with the possibilities of the educational information systems allows not only to improve the quality of studying physics but also to create conditions for the development of the students' engineering thinking, the skills to work with digital tools and competencies, necessary for efficient operation in a modern agro-industrial complex.

Keywords — *agricultural engineers, agricultural machinery, agro-industrial complex, engineering competencies, innovative technologies, interdisciplinary approach, physics, professional training.*

I. INTRODUCTION

The modern agricultural and technical industry places high demands on professional training of engineers, who must master not only deep theoretical knowledge but also practical skills, and be ready to use innovative technologies. Traditional approaches to training often fail

Online ISSN 2256-070X

<https://doi.org/10.17770/etr2025vol3.8529>

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to fully ensure the development of the competencies that are necessary for the work in the context of digital transformation of the agricultural sector.

The main problems that need to be solved:

1. Insufficient digitalization of the educational process: the lack of a holistic information environment, capable of combining learning, practical training and data analysis, which creates a gap between theoretical knowledge and its practical application.

2. Limited personalization of learning: the diversity of the students' levels of training, interests and individual characteristics remains without due attention due to the lack of adaptive tools, which negatively affects the efficiency of the educational process.

3. The lack of resources for practical training: Limited access to modern equipment, specialized software and simulators makes it difficult to develop practical skills, necessary for the future professional activities.

4. Insufficient integration of interdisciplinary approach: Traditional educational programs do not take into account the need to integrate knowledge from different fields, such as engineering, agronomy, information technology and management.

5. Difficulties in communication between the students and the teachers: outdated methods of interaction and insufficient feedback reduce the quality of communication and hinder the development of independence and the responsibility skills in the students.

6. The lack of tools for the analysis of the educational process: the lack of systems for monitoring and analysing the students' performance limits the ability to timely adjust the curricula and an individual approach to learning.

To solve these problems, it is necessary to create and implement an educational information environment that will combine modern technologies, methods and organizational approaches. Such an environment should be focused on developing the professional competencies of engineers in the agricultural and technical sector, adapting to the changing market requirements and ensuring high-quality training of specialists.

The issues, related to the educational information environment in the higher education system, have remained the key topic of scientific discussions already over the past decades. A significant number of investigations have been devoted to the analysis of both positive and negative effects of using digital technologies in the educational process.

Integration of modern technologies into education has been a strategic priority for many universities in the recent years [1]. Since the learning practices and technological tools are changing, such a training has to evolve [2]. The online technologies, engineering programs, and the internet access facilitate the transition to learning in an information-educational environment; yet immersion in the learning environment goes beyond the learning tools [3]. Wang, J., Tigelaar, D., Admiraal, W. consider the use of digital educational resources, as well as the integration

of theoretical and practical aspects of learning [4]. In the article by Zalewski, J., Novak, G., Carlson, R. E., attention is paid to the identification of the main challenges, faced by teachers, and finding optimal solutions to improve the quality of the students' training [5]. The efficiency of the content of general technical disciplines and the methodology of the teaching technology is determined by the performance of professional activities [6]. The main features of the development and implementation of practice-oriented classes, activation and stimulation students' cognitive interest in mastering the necessary profession are considered by Ivanov, M., Parnikova, T., Gulyaev, V., & Petrov, N. [7].

However, Lyu et al. [8] noted that the engineering students often find it difficult to identify the relevance of their disciplines to their future careers, suggesting a need for further research in this area. In training of agricultural engineers, new approaches are needed that are associated with interdisciplinary training and the use of modern technologies [9], [10].

At the same time the pragmatic approach of many modern applicants leads to the fact that they focus on studying the disciplines, directly related to their future specialty, reducing attention to other subjects that they consider less important. In particular, this concerns such a scientific and natural discipline as physics [11], [12].

Despite the fact that scientific and methodological works provide a comprehensive analysis of this issue, they often do not offer specific solutions. In this regard it is important to develop methodological materials that define in detail the system of the teaching methods and tools for a particular discipline. Such materials should be aimed at the formation and development of professional qualities of the students, as well as at the elimination of the existing problems. The creation of methodological materials that not only analyse the problem but also offer solutions is a significant step in improving the quality of education.

The aim of this research is to develop and implement the key areas of development of the digital educational technologies and author's content for the physics course, providing the teachers with theoretical and practical support in training the engineers in a modern information and educational environment to improve the quality of their professional training. The following methods were used to evaluate the developed methodology: digital questionnaires to analyse the students' motivation, adaptive online testing to assess their knowledge, simulation case methods to test practical skills, machine learning methods to identify the importance of disciplines, and educational analytics for a comparative analysis of assignment completion by the students in the experimental group (EG) and in the control group (CG).

II. MATERIALS AND METHODS

The information and educational environment is a set of information resources, technologies, tools and methods that ensure the organization, support and improvement of

the educational process. It is based on the integration of the traditional and digital teaching aids, using modern information and communication technologies. The information environment provides opportunities for the integration of modern technologies into the educational process, especially in physics, which requires a high level of visualization, modelling and practical work. Modern approaches to teaching physics to the engineers include the use of practice-oriented methods, such as professional tests, case methods and digital simulators. These methods allow integrating theoretical knowledge with the real-life tasks, developing engineering thinking and forming professional competencies, necessary for successful work in an agro-industrial complex.

A. Professional tests

Training engineers in an agricultural and technical sector while studying a course in physics has a number of features that are determined by the specifics of their future professional activities. A practical orientation of the physics course for engineers is the key aspect, as it allows the students to understand better how the physical laws and principles are applied in their professional activities. A practical orientation of the physics course for engineers ensures being informed about the knowledge and skills that are necessary to solve real problems in agriculture and technical engineering. Therefore, an important factor for the formation of professional competencies is the use of educational tasks that are close to further professional or research activities [13] – [17]. In addition, it allows the students not only to learn the theoretical laws of physics but also to apply them in practical situations that meet the specifics of the agricultural sector. Examples of how to use information and the educational system in studying physics for the engineers:

1.1. Section “Mechanics”: virtual modelling of the operation of agricultural equipment (tractors, ploughs, combines); studying the stability of machines on slopes or calculating the friction forces between the wheels and the ground (Fig. 1).

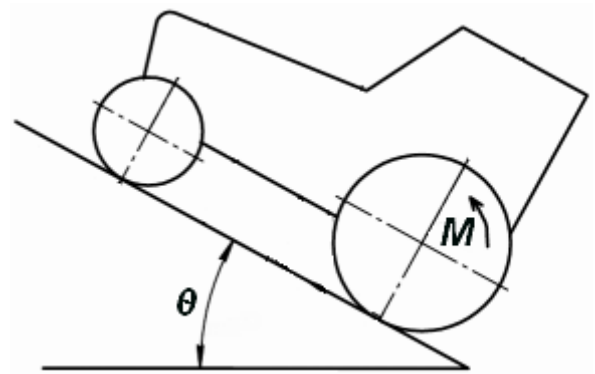
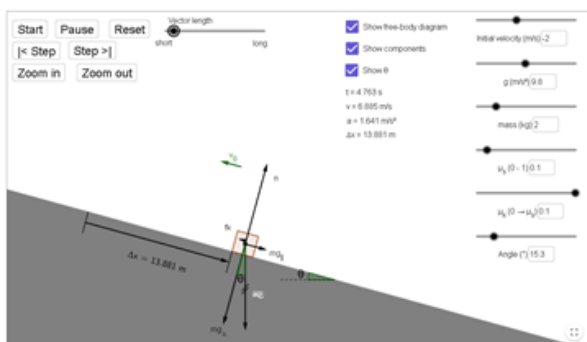


Fig. 1. Virtual modelling of the tractor movement on slopes, or calculation of the friction forces between the wheels and the soil.

1.2. Section “Hydrodynamics”: modelling of the irrigation systems (calculation of the water pressure in the pipelines and the pump efficiency) (Fig. 2).

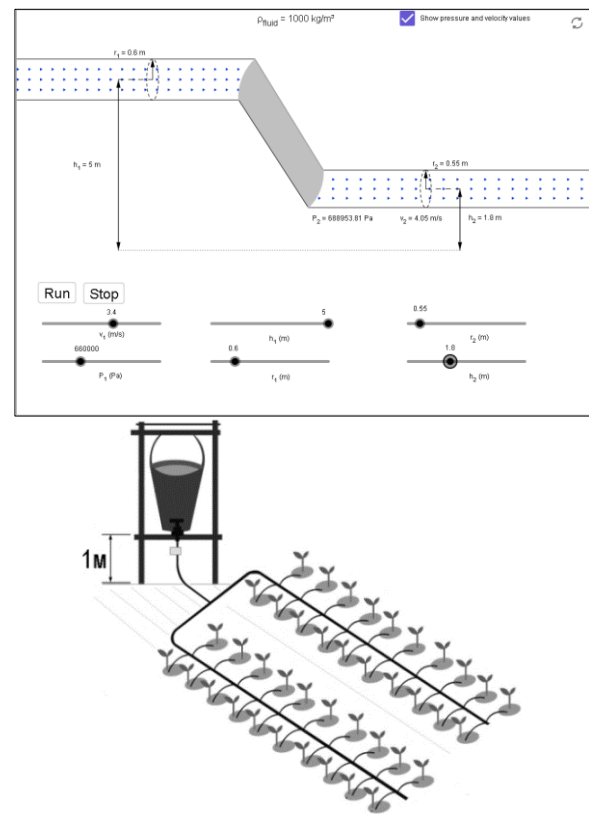


Fig. 2. Virtual modelling of the irrigation systems.

1.3. Section “Thermodynamics”: virtual experiments on calculating the heat transfer in the grain drying systems or the greenhouse operation; study of the operating principles of internal combustion engines.

1.4. Section “Electromagnetism”: simulation of the operation of electric motors, generators and sensors; calculation of the parameters of electrical circuits for the automation systems.

Such an approach to studying physics allows the engineers not only to master the theoretical foundations

but also to apply them in practice, which increases their professional readiness to work in the agricultural sector.

B. The Case method

The case method involves students who are working with real or simulated situations that require analysis and decision-making, based on the knowledge of physics. For example:

2.1. Selecting an irrigation system for a specific crop: calculating the parameters of a drip irrigation system, based on the data about the soil and climate.

2.2. Optimization of the tractor engine operation: analysis of the thermodynamic processes in the engine to increase its coefficient of efficiency.

2.3. Solution of problems in the grain storage: analysis of the heat and moisture exchange processes in the storage facilities to prevent spoilage of the products.

As a result of using the case method in studying physics for the engineers, the following is achieved:

1. Increased motivation and engagement: the students actively participate in solving practical

problems, seeing the real importance of physics for their profession. For example, a case study on choosing an irrigation system, based on hydrodynamic calculations, generates interest and stimulates the application of knowledge.

2. Developing analytical thinking: working with cases requires deep data analysis, application of physical laws and making informed decisions. For example, calculating the stability of a tractor on a slope helps to understand the practical application of mechanics.

3. Development of practical skills: the case solution involves modeling of processes, calculations and using the tools of analysis. For example, calculating the operating parameters of a grain dryer helps to master the laws of thermodynamics.

4. Strengthening of interdisciplinary links: the case method allows to integrate physics with other disciplines, such as mathematics, chemistry and biology. For example, calculating the heat losses in greenhouses involves knowledge from various fields.

5. Training for real professional situations: the students gain experience in solving problems, similar to those they will encounter in their work. For example, the analysis of the grain storage problems through the heat and moisture exchange processes.

6. Assessment of the students' competencies: the case method makes it possible to objectively assess the level of the students' training through the quality of solutions and proposed approaches. For example, completing a case study on optimizing the operation of the internal combustion engines allows one to measure the level of their knowledge and skills.

The case method promotes a deeper understanding of physics, it develops professional competencies and trains the engineers how to solve real problems, making training more practice-oriented and efficient.

C. Digital simulators

The use of virtual laboratories and software to simulate the physical processes, related to engineering. For example:

3.1. Modelling the performance of the agricultural equipment: The analysis of the tractor dynamics by using the simulators of mechanical systems.

3.2. A study of hydraulic processes: modelling the operation of the pumping systems, calculation of the pressure losses in pipelines.

3.3. Working with thermal systems: virtual study of thermal processes in the grain dryers and greenhouses.

The use of digital simulators in studying a physics course makes it possible to study complex processes without a risk to damage the equipment; it increases the students' interest through the use of modern technologies, and also develops their skills in the work with digital tools.

The use of a project-based learning, professional trials, case studies and digital simulators in teaching physics to the engineers significantly enriches the educational process. First, the students gain a deeper understanding of theory because the physical laws that they study are illustrated through their application to professional engineering-related problems. Second, the practical orientation of training contributes to the development of professional competencies: the students solve real problems, create models and complete projects, which trains them for the future work. In addition, such methods increase motivation and involvement in the learning process, as they make knowledge meaningful and useful for the future profession. As a result, education becomes not only more interesting but also focused on the practical implementation of knowledge.

III. RESULTS AND DISCUSSION

During the pedagogical experiment the main task was to evaluate the efficiency of developing the professional competence of the future engineers by using various approaches and methods, such as professional tests, the case methods and digital simulators.

A total of 456 students of specialty 208 "Agroengineering" participated in the experiment. The experimental group (EG) is trained, using a new method; classes in the control group (CG) were held according to the traditional method.

To study the actual state of the students' readiness for a professional activity, the following tools were developed:

- Questionnaires to determine students' interest in professional activities.
- Test assignments to assess knowledge of special disciplines.
- Cases for testing practical skills.
- Criteria for evaluation of the results of design and laboratory works.

To conduct an initial diagnosis of the level of competence, we conducted a survey to identify the level of interest and awareness of the importance of the professional disciplines (Table 1).

TABLE 1. SURVEY QUESTIONS TO IDENTIFY THE LEVEL OF INTEREST AND AWARENESS OF THE IMPORTANCE OF PROFESSIONAL DISCIPLINES

Closed questions:	Answers
How interesting is discipline "Physics" to you?	1 – not interesting at all, 5 – very interesting
How do you evaluate the importance of physics for your professional training?	1 – as insignificant, 5 – as very significant
What topics from the physics course do you find most useful?	Select from the list: mechanics, hydrodynamics, thermodynamics, electromagnetism
Open questions:	
What would you like to change in the methodology of teaching physics?	
How can knowledge, gained in the physics classes, be used in engineering?	
What practical problems, related to physics, do you find most interesting?	

Conducting a survey allows us to identify the proportion of students with low, medium and high levels of interest, as well as to determine the extent to which the students understand the link between the professional disciplines and the real engineering tasks. This helped us also to identify elements of the course or teaching methods that stimulate the students' interest. The results of this stage of the experimental work are presented in Table 2.

TABLE 2. RESULTS OF A SURVEY TO IDENTIFY THE LEVEL OF INTEREST AND AWARENESS OF THE IMPORTANCE OF PHYSICS

Parameter	Low level (1-2)	Medium level (3)	High level (4-5)
Interest in discipline "Physics"	15	45	40
Awareness of the importance of the discipline	10	35	55
Preference to practical classes	5	25	70

As regards the students' interest in professional competence of the future engineers, we found that the majority of the students are aware of the importance of physics (55% high level), yet the interest in the discipline requires improvement (40% high level), and the students' motivation can be increased by the practice-oriented teaching methods (preferably, 70%).

During the pedagogical experiment of the experimental group, the following measures were carried out to organize the educational process:

1. Conducting professional tests: performing practical tasks in educational laboratories or at agricultural enterprises.
2. Using the case method: analysis and solution of real engineering problems.
3. The work with digital simulators and programs (AutoCAD, SolidWorks, modelling systems of hydraulic processes).

For the control group the training was conducted using standard methods (lectures, seminars, the traditional laboratory work).

As shown by the results (Table 3) of the pedagogical experiment (monitoring the students' progress in completing the assignments, conducting intermediate tests, surveys and questionnaires), the implementation of the created methodology for the development of the professional competence of the future engineers in the process of studying physics had a positive impact on the level of development of this competence.

TABLE 3. DYNAMICS OF FORMATION OF PROFESSIONAL COMPETENCE OF THE FUTURE ENGINEERS (%)

Level of professional competence	At the beginning of the experiment		At the end of the experiment	
	EG	CG	EG	CG
High level	30	28	48	32
Medium level	40	42	42	43
Low level	30	30	10	25

Thus, in the experimental group (EG) 48% of students achieved a high level (previously 30%), and 42% of students achieved an average level (previously 40%). In the control group (CG) 32% of students achieved a high level (previously 28%), and 43% achieved an average level (previously 42%).

CONCLUSION

The results, obtained during the experiment, indicate a significant influence of the proposed methodology on increasing the level of professional competence of the future engineers. An increase in the proportion of the students with a high level of readiness in the experimental group (48% versus 32% in the control group) and a significant decrease in the indicator of a low level of formation (by 20% versus 5% in the control group) indicate the efficiency of the application of the developed digital educational technologies and the corresponding methodology.

Comparison of the data with the results of research by other authors confirms the general trend according to which the integration of innovative approaches into the teaching of fundamental disciplines, in particular physics, has a positive effect on the professional training of the students. Our work is not limited to a general assessment of the impact of innovative methods; we have focused on the practical orientation of the tasks specifically in the field of engineering and demonstrated the results in particular professional contexts. Thus, along with the

introduction of virtual laboratories and simulators, we developed a series of tasks, related to real production and technological processes in agriculture, which allowed the students to see immediately the practical significance of the knowledge they are gaining. In addition, we created, as part of the experiment, a digital educational environment in which the training modules were supplemented with materials and cases from the partner employers, thereby strengthening the professional focus of training and motivating the students to study physics in depth in the context of their future specialty. It is this complex integration of fundamental knowledge and real professional tasks that allows us to say that the presented experience goes beyond general recommendations and provides a specific tool for the improvement of the level of training of the future engineers.

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Application of Artificial Intelligence to Automatically Verify Student Calculations in Higher Education Institutions

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Abstract— Artificial Intelligence (AI) is becoming a key tool in education, automating the verification of students' calculations, which is especially important for disciplines involving mathematical and technical calculations. The article focuses on improving the digital literacy of students and teachers through the integration of innovative technologies. The use of AI transforms learning by promoting individualization of the process, instant feedback and in-depth mastering of the material. The perspectives of adaptive educational platforms that analyze the level of preparation of students and build personalized learning trajectories are discussed. The challenges of AI implementation are also discussed, including algorithm improvement, ethical issues of automated assessment, and integration with existing educational systems. The study evaluated the effectiveness of implementing AI systems to check students' calculation papers. The results showed that the use of artificial intelligence allowed to reduce the time of work verification by 60-70%, to increase the accuracy of assessment by 25-30% due to minimization of the human factor, and to increase student performance by 15-20% due to individualized recommendations. It is concluded that the use of artificial intelligence in the verification of calculations not only increases the efficiency of the educational process, but also develops students' skills in working with digital

technologies, which are necessary in modern conditions. The introduction of artificial intelligence into the educational environment contributes to the creation of adaptive, interactive and innovative approaches to learning, improving the quality of education and its accessibility.

Keywords— artificial intelligence, check automation, higher education, pedagogical experiment.

I. INTRODUCTION

In today's world, global digitalization has had a significant impact on all aspects of human life, including education. The use of information technologies is becoming an integral component of the educational process, contributing to its efficiency. One of the key directions of digitalization of education is the integration of artificial intelligence (AI) to automate various processes, in particular, the verification of calculation works of applicants for higher education.

The relevance of this study is due to the need to adapt the educational system to the requirements of the digital age. With the growing number of applicants for higher education and the volume of educational materials, traditional methods of checking student papers are

Online ISSN 2256-070X

<https://doi.org/10.17770/etr2025vol3.8551>

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becoming less effective. The integration of artificial intelligence allows solving a number of problems, such as limited time of teachers, subjectivity of assessment and the need for quick feedback. It is especially important to implement such technologies in developing countries, including Ukraine, where educational institutions face the challenges of optimizing processes in the context of limited resources.

The rapid development of artificial intelligence technologies creates a need to study their impact on the educational process. This includes assessing how effective such solutions are in improving the quality of learning, as well as finding the best ways to integrate them into the educational environment.

In November 2023, the Organization for Economic Cooperation and Development updated its definition of AI, noting that “an artificial intelligence system is a machine system that, in order to achieve explicit or implicit goals, makes inferences from the input data it receives about how to generate inputs such as predictions, content, recommendations, or decisions that can affect the physical or virtual environment” [1].

In recent years, researchers have been actively exploring the implementation of AI in educational environments, analyzing its effectiveness, benefits and challenges. Scientists offer different approaches to the use of AI in education, considering both technological and pedagogical aspects of this process.

Norbert Annus [2] explores the impact of intelligent educational software on the learning process. Based on international research, he presents 15 educational software solutions that, thanks to their intelligent features, accelerate and simplify the learning process, supporting differentiated and more personalized learning.

In [3], the researchers review the application of machine learning algorithms to automatically grade student papers. They provide practical recommendations for the selection and implementation of such algorithms in educational environments, analyzing their efficiency and accuracy. The main focus is on algorithms that can improve the objectivity and speed of assessment, reducing the burden on teachers. The works [4] – [6] describe modern approaches and technologies of artificial intelligence application in higher education, data mining methods that can be used to assess and predict students' academic performance, which allows to identify patterns in academic achievements, identify potential risks of falling behind and adapt the educational process to individual student needs. The authors Chen L., Chen P., Lin Z [7] discuss the challenges associated with the introduction of AI in education, such as ethical issues, the need to train teachers to work with new technologies, and ensuring equal access to innovation for all participants in the educational process.

A wide range of issues, also technical aspects of AI implementation, analyzing both opportunities and challenges arising from the integration of digital technologies in engineering is shown in Crawford, K. [8].

The work of [9] is devoted to the use of AI in the educational process of training specialists to work in the conditions of digital transformation of production, considering the issues of integration of innovative digital tools in engineering training and production. Roll, I., & Wylie, R consider the possibilities of personalized learning and optimization of teaching methods [10].

Ukrainian scientists are also actively studying different aspects of the implementation of artificial intelligence systems in the educational sphere, considering their opportunities, challenges and prospects. Among the leading researchers of this topic we can mention [11] – [14]. and others. The results of their work contribute to the expansion of opportunities for the use of AI in domestic education, the formation of modern approaches to the digital transformation of the educational process and the development of strategies for the effective implementation of the latest technologies.

In general, artificial intelligence, according to these definitions and descriptions, covers the development of machines that have a certain level of intelligence and are capable of performing human-like functions, in particular cognitive, learning, decision-making and adaptation to the environment. In the educational environment, AI facilitates the automation of routine tasks, personalization of the learning process, adaptive learning and improved assessment of students' knowledge. At the same time, the issue of the effectiveness of AI systems in the verification of computational works, in particular, regarding the correctness of the interpretation of physical formulas, the logic of solution execution and compliance with methodological requirements, remains insufficiently investigated. The purpose of this study is to analyze the theoretical and practical aspects of the application of artificial intelligence in the educational process, to assess its impact on the effectiveness of learning, as well as to consider the ethical, social and technical aspects of the integration of artificial intelligence in educational institutions, which will make it possible to formulate recommendations for its effective implementation and use.

II. MATERIALS AND METHODS

Modern educational process needs innovative approaches to the verification of calculation tasks in exact sciences, particularly in physics. In order to train engineers at the master's level to familiarize them with modern developments, teaching tasks are formed on the basis of modern scientific works [15; 16], which contributes to a faster integration of a specialist into the production environment. Traditional methods of assessment require a lot of time and effort of teachers. The introduction of artificial intelligence into this process allows to automate verification, improve the accuracy of assessment and provide students with quick feedback. At the same time, the issue of the effectiveness of artificial intelligence systems in the verification of calculation works, in particular, regarding the correct interpretation of physical formulas, the logic of solution execution and compliance with

methodological requirements, remains insufficiently researched.

The methodology of artificial intelligence application for automated physics examinations is based on algorithms of machine learning, symbolic mathematics and natural language processing. It is aimed at analyzing students' decisions, identifying errors and providing detailed feedback, which allows to significantly increase the objectivity of the check and accelerate the educational process.

The methodology also involves integrating the system with educational platforms such as Moodle, Google Classroom and Microsoft Teams, which allows automating the verification process, tracking student performance and generating progress reports. Teachers can customize the validation parameters, setting the level of assessment rigor, while students get immediate access to the results and recommendations on how to improve their skills.

Moodle is one of the most popular LMSs, offering flexibility through a system of plug-ins and integration with external tools. For automated checking of calculations, Moodle uses the STACK plugin, which allows you to analyze mathematical and physical expressions taking into account symbolic transformations. It connects Maxima CAS (Computer Algebra System), which allows you to automatically evaluate numerical and algebraic answers by comparing them with reference solutions. Additionally, Python libraries (SymPy, NumPy) can be integrated, creating custom plugins to analyze students' solutions, and OCR tools (Tesseract, MyScript) can be used to process handwritten formulas and equations. Another approach is to use Google Colab and API, where calculation files are uploaded for automatic validation and TensorFlow/PyTorch-based neural network models analyze typical student errors to help tailor feedback.

At the verification stage, the system divides the solution into key elements: initial data, applied formulas, sequence of calculations and final result. The analysis includes verification of correctness of numerical calculations, equivalence of mathematical expressions, correct use of physical laws and observance of dimensions. The use of symbolic mathematics methods makes it possible to determine whether the presented expressions are equivalent to the reference solution, even if the student used a different calculation method. An important part of the methodology is the identification of typical errors. The system analyses inaccuracies, including arithmetic errors, incorrect choice of formula, incorrect application of physical laws, and incorrect rounding. It also evaluates the logical structure of the solution: sequence of actions, correctness of intermediate calculations and correctness of using units of measurement. After analysis, the system generates feedback, providing the student with a detailed analysis of errors and an explanation of the correct solution method. Depending on the complexity of the task and the student's level of preparation, personalized learning adjustments are possible: recommendations for additional materials, analysis of similar examples, and individual assignments to

eliminate gaps in knowledge. Machine learning methods are used to improve the accuracy of verification, which allows analyzing a large database of student solutions and identifying common errors. Natural language processing technologies are used to analyze explanatory texts, and neural network models help recognize handwritten mathematical expressions. This makes verification as accurate as possible and adaptable to different problem-solving styles.

III. RESULTS AND DISCUSSION

It was decided to conduct research on the effectiveness of using artificial intelligence for automated verification of calculation papers in physics among applicants for higher education specialty 208 "Agroengineering" of the institution of higher education "Podolsk State University", as well as to assess the accuracy of verification, the ability to detect errors and the quality of the provided feedback.

The procedure of the experiment implies several main stages. The stages of the experiment are reflected in Table 1.

TABLE 1 STAGES OF THE EXPERIMENT

Stage	Description
Preparation of the AI system	Formulation of evaluation criteria and setting up algorithms for recognizing physical expressions.
Selection of participants	Distribution of students into experimental and control groups.
Task execution	Solution of identical calculation works by both groups.
Work verification	Evaluation of works: in the control group – by the teacher, in the experimental group – by the AI-system.
Comparing results	Analysis of differences in the grades, accuracy of error detection and efficiency of evaluation.
Analyzing participants' perceptions	Discussion with teachers and students on the quality of the automated check and its possible application.

The first step is the preparation of the AI-system, including the formulation of evaluation criteria and setting up algorithms for recognizing physical expressions. Next, the selection of participants is made, in which the students are divided into two groups: experimental and control. The next stage is task performance, where both groups solve the same computational work. After that, the works are checked, and in the control group the evaluation is carried out by the teacher, and in the experimental group – by the AI system. An example of a calculation work is shown in Fig. 1.

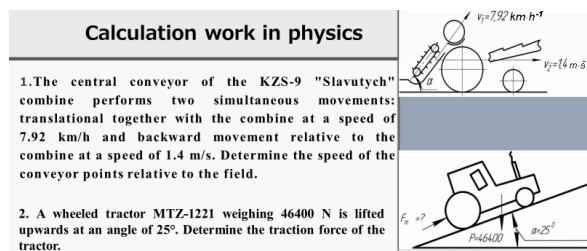


Fig. 1. Tasks for calculation work in physics for students of the specialty "Agroengineering".

The final step is to analyse the participants' perceptions, involving discussion with instructors and students about the quality of the automated checking and its potential for integration into the teaching process.

During the automated verification of this calculation work by artificial intelligence, various errors related to the processing of numerical data, interpretation of physical quantities and correct application of formulas were detected.

In the first task, where the movement of the central conveyor of the KZS-9 "Slavutich" combine harvester is considered, errors were found in calculations of the total velocity of the conveyor point relative to the ground. The artificial intelligence incorrectly took into account the directions of motion and misinterpreted the units of measurement, because the speed is given in different systems (kilometers per hour and meters per second). The students used different calculation methods (vector addition and scalar approach), which led to differences in the format of the answer record, which the system perceived as incorrect.

In the second task, concerning the determination of the tractive force of the MTZ-1221 tractor when driving at an angle of 25°, there were difficulties in recognizing the physical components of the force. Artificial intelligence failed to take into account differences in the use of trigonometric functions (e.g., sine or cosine of an angle) depending on the chosen solution method. Errors were also found in the correctness of recognizing the force of gravity and its decomposition into components, as different students used alternative forms of writing equations, the results improved if the students were pre-trained and fluent in the method of analyzing and investigating the motion of energy vehicles [17].

In addition, the automated checking system misinterprets the rounding of numbers, resulting in a student's answer containing minor deviations from the expected value being labeled as incorrect. Difficulties were also found in processing graphical elements or explanations if the student supplemented the calculations with diagrams or explanations in a non-standard format. Thus, automated checking of such calculation papers has some limitations that may affect the accuracy of the assessment. In order to reduce the number of erroneous rejections of correct answers, it is necessary to improve algorithms for recognizing physical equations, to ensure adaptability to different solution methods, and to improve mechanisms for

analyzing graphical materials in students' answers. At the final stage, statistical analysis was carried out, which involved processing the obtained results, determining the mean values of the scores, analyzing the deviations, and evaluating the differences between the two methods of verification. The results of the validation are shown in Fig. 2.

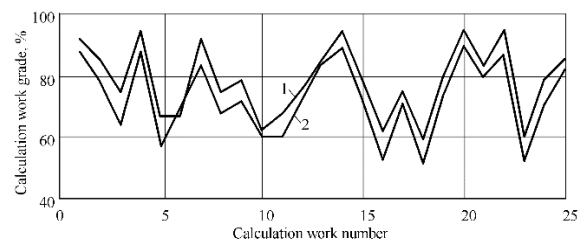


Figure 2. Results of the test: 1 – experimental group; 2 – control group.

The analysis showed that, although automated verification provides a significant acceleration of the evaluation process, it has certain limitations in cases where student solutions differ from the template solutions but remain correct. In particular, in the control group, where teachers performed the verification, the percentage of erroneously low marks was lower, which is explained by the teacher's ability to analyze the logic of the student's solution, not only the final result. At the same time, in the experimental group, where the AI performed the verification, a more rigorous assessment was observed, as the system was oriented to predetermined answer patterns. This confirms the need for further improvement of automated assessment algorithms to take into account different physical approaches to problem solving.

Table 2 displays the distribution of students' performance levels in the control and experimental groups after validation. In the experimental group, the assessment was carried out by artificial intelligence, while in the control group the verification was carried out by teachers. The comparison of the obtained results allows us to assess the impact of automated testing on the level of material assimilation and assessment accuracy.

TABLE 2 RESULTS OF THE INSPECTION

Levels	Experimental group	Control group
Elementary	12%	9%
Medium	44%	27%
Sufficient	25%	42%
High	19%	22%

The results of the verification showed that the use of artificial intelligence for automated assessment of calculation works has an impact on the distribution of students' performance levels. In particular, in the experimental group, where the verification was performed with the help of AI, there is an increase in the proportion of students with an initial level (12%) compared to the control

group (9%). There is also a decrease in the number of students with sufficient level in the experimental group (25%) compared to the control group (42%), which may indicate a more accurate and rigorous AI approach to assessment. In addition, the proportion of students with a high level in the control group (22%) is higher than in the experimental group (19%), which may be due to certain limitations of AI algorithms in accounting for creative or non-standard solution methods.

A survey of students who participated in the experiment showed that 78% of the respondents positively evaluated the automated check and noted that the quick feedback helped them better understand their mistakes. At the same time, 22% of students indicated that the automated assessment was sometimes too harsh or unfair, especially in cases where they used non-standard solution methods. Some students expressed concern that the AI was not always able to evaluate the logic of a solution in the same way that an instructor does. They noted the need to refine the evaluation algorithms to accommodate different approaches to task completion.

IV. CONCLUSION

The results of the study confirm that the use of artificial intelligence for automated verification of physics calculations significantly increases the objectivity of evaluation, reduces the verification time and improves the quality of the educational process. In contrast to traditional methods based on manual checking by a teacher or simple automated systems, the proposed approach includes complex analysis of solutions taking into account the logic of calculations, application of physical laws and observance of dimensions.

Our research differs from other works in the field of automated checking of calculations in the fact that it offers a comprehensive and adaptive approach that takes into account not only the correctness of the final result, but also the entire logic of problem solving. Unlike traditional systems focused on template comparison with a reference answer, our methodology analyzes intermediate calculations, logical sequence of actions, and correctness of the use of physical laws.

Thus, our study not only confirms the effectiveness of using AI in educational processes, but also proposes an innovative method for checking computational work that combines intelligent decision analysis, personalized feedback, and adaptive scoring system, making it more flexible and accurate than existing approaches.

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Innovative Technologies in Teaching Theoretical Mechanics for Agri-Engineers

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Abstract — The article deals with innovative technologies of teaching theoretical mechanics for agro-engineering education. This discipline forms the basic engineering knowledge critical for the agro-industrial complex. In the context of digitalization, it is relevant to improve teaching methods using digital simulators, interactive platforms and adaptive online courses that visualize complex mechanical processes and facilitate the understanding of theoretical foundations. Special attention is given to the practice-oriented approach that allows students to apply knowledge in real engineering problems. The benefits of innovative technologies include: increasing the accessibility of educational material, developing analytical and engineering skills through simulations, reducing the burden on teachers by automating the verification of calculations, and developing the systemic thinking necessary to solve interdisciplinary problems. The results of the study showed that the integration of innovative technologies into the process of learning theoretical mechanics contributes to increasing the level of material assimilation by 30–40%, increasing student motivation by 30% and improving the quality of engineering calculations by 25% compared to traditional teaching methods. It is concluded that the introduction of innovative technologies in the teaching of theoretical mechanics allows optimising the educational process, making it more interactive, practical and adaptable to the individual needs of students. In order to further

improve the quality of engineering education, it is recommended to strengthen interdisciplinary integration, to involve experts from the agro-industrial sector in the development of teaching materials, and to make more active use of digital educational ecosystems that ensure the continuous professional development of future specialists.

Keywords — *agroengineering, digital simulations, innovative technologies, interactive learning, theoretical mechanics.*

I. INTRODUCTION

With the development of digital technologies and automation in the agricultural sector, there is a need to modernise the methods of teaching technical disciplines, especially theoretical mechanics. The use of innovative approaches makes it possible to provide students with the necessary knowledge and skills to effectively solve practical problems related to the design, operation and maintenance of agrotechnical equipment. The modern development of agroengineering requires a high level of theoretical and practical training of specialists capable of applying knowledge of theoretical mechanics to solve applied problems. However, traditional teaching methods often do not provide a sufficient level of material

Online ISSN 2256-070X

<https://doi.org/10.17770/etr2025vol3.8553>

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assimilation, which reduces the effectiveness of the educational process.

The main problems are: low level of students' motivation to study complex theoretical disciplines; insufficient integration of digital technologies and interactive teaching methods; complexity of visualization of mechanical processes and phenomena; insufficient practical orientation of the course, which makes it difficult to apply the acquired knowledge in future professional activity.

Over the past decades, issues related to the educational information environment in higher education continue to be at the centre of academic discussions. Johnson A., Lee B. [1], Kumar S., Patel R. [2], Lopez R., Gonzalez M. [3], Martinez L., Rodriguez P. [4], Smith J., Brown T. [5], Wang X., Li H. [6] and others.

The combination of traditional teaching methods with online components in teaching theoretical mechanics to agroengineering students is reviewed [1], [2], [3], [4]. The authors analyse the advantages and challenges of blended learning and its impact on students' academic performance. Methodological foundations and pedagogical strategies that allow effective integration of modern information technology in the teaching process are analysed in the work of Zheng, Y. Y. et al.

Xiaomin Shan proposes an innovative approach to teaching theoretical mechanics based on the concept of outcome-oriented education. The author points out the limitations of traditional methods that focus solely on knowledge transfer and justifies the need to introduce a student-centred approach to develop students' autonomous thinking, creative skills and practical competence [7].

Smith, J., Brown, T., Wang, X., Li, H. consider the implementation of innovative methods of teaching theoretical mechanics in the context of agroengineering [5], [6]. The authors consider the use of online simulations, interactive modules, project-based learning and augmented (AR) and virtual reality (VR) technologies in teaching theoretical mechanics to improve student learning. Applying the experience of mathematical modelling and analysis [8], [9] when considering engineering processes allows students to clearly form cause-and-effect relationships and improve learning of even complex material.

A significant contribution to the development of methods of teaching theoretical mechanics using innovative technologies, contributing to the improvement of the quality of education for future agro-engineers was made by: Smirnova N. E., Prishlyak V. M., Boychuk I. P., Morozova O. I., Bat M. I., Janelidze G. Yu. I., Bat M. I., Janelidze G. Yu. V. and others.

The authors [10], [11], [12] consider the introduction of interactive teaching methods for students of agroengineering specialties. The authors analyse the effectiveness of using such technologies as multimedia presentations, virtual laboratories and online tests in increasing the level of material assimilation by students.

Smirnova N. E. analyses modern approaches to teaching theoretical mechanics in the context of agrarian and engineering education. The author points out the shortcomings of traditional methods focused solely on the transfer of knowledge, limiting the development of practical skills and critical thinking of students [12].

Despite many years of scientific discussions, the issues related to the development and implementation of educational information environment in the system of higher education remain relevant. Some aspects, such as the effectiveness of digital technologies in learning, the adaptation of educational platforms to the individual needs of students, as well as the impact of the information environment on the quality of the educational process, require further study. The lack of elaboration of these issues emphasizes the need for additional research aimed at improving the educational ecosystem and increasing its efficiency.

This confirmed the purpose of our research, which was to develop and argue for effective methods of teaching theoretical mechanics for training future agroengineers using innovative educational technologies. In order to assess the effectiveness of innovative technologies in teaching theoretical mechanics for agroengineers, a combination of theoretical and empirical methods was employed. The theoretical methods included analysis and synthesis of scientific literature, modelling of educational processes, generalisation and systematisation of data. The empirical methods comprised pedagogical experiment, observation of the learning process, questionnaire survey of students and teachers, knowledge testing, analysis of teaching materials and digital educational resources. In addition, statistical processing of the data was carried out, including quantitative and qualitative analysis, as well as expert evaluation of the effectiveness of the proposed methodology. This comprehensive approach facilitated the acquisition of an objective depiction of the impact of innovative technologies on the training of future agroengineers.

Taking into account these challenges, it is necessary to introduce innovative technologies in the teaching of theoretical mechanics, which will contribute to improving the quality of education, enhancing the understanding of the material and developing the practical skills of agricultural engineering students.

II. MATERIALS AND METHODS

Application of digital technologies in the teaching of theoretical mechanics contributes to a more effective assimilation of the material by students. In particular, the use of specialized software allows the study of complex mechanical phenomena and contributes to their better understanding.

One of the key areas of digitalization of the teaching process is computer simulation, which allows creating and analysing interactive models of mechanical systems. Such models help students gain a deeper understanding of the regularities of body motion, analyse the equilibrium of structures and study dynamic processes. Modern software

tools such as MATLAB, ANSYS, COMSOL Multiphysics, FreeCad, Autodesk Fusion, Inventor Nastran, allow to perform numerous calculations, visualize results and conduct experimental studies in a virtual environment.

In the course of theoretical mechanic's students study the kinematics and dynamics of mechanisms, in particular, the crank-rod mechanism (CRM), which is the basis of the piston internal combustion engine.

To simulate the operation of the piston mechanism of the tractor and assess the load on its parts in different operating modes, you can use software packages such as MATLAB, FreeCad or MSC Adams.

For example, performing kinematic and dynamic analysis of the tractor piston mechanism and estimation of loads and mechanical stresses includes three main steps:

1. Kinematic analysis – determining the position, velocity and acceleration of the piston, connecting rod and crankshaft.
2. Dynamic analysis – calculation of forces of inertia, moments of forces, reactions in joints.
3. Mechanical stress evaluation – analyse stresses and deformations in piston mechanism parts.

Students proceed to the study of crank mechanism by basic concepts and visualization (Fig. 1). To deepen the knowledge when familiarizing with the algorithm of investigation of working mechanisms, it helps well to study the results of modern scientific research in this industry [13-17].

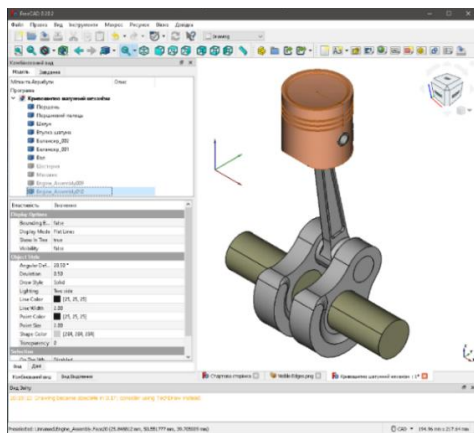


Fig. 1. 3D model of crank connecting rod mechanism in the FreeCad program.

At the first stage, they work with drawings and schematics of the mechanism, determining the main geometric parameters such as the radius of the crank R , the length of the connecting rod L , the position of the piston x , the angular velocity of rotation ω , θ - the angle of rotation of the crank. Using these values, students perform simple calculations such as finding the position of the piston at different phases of crank motion. This helps them to develop an understanding of the kinematic features of the mechanism and prepare for further calculations (Fig. 2).

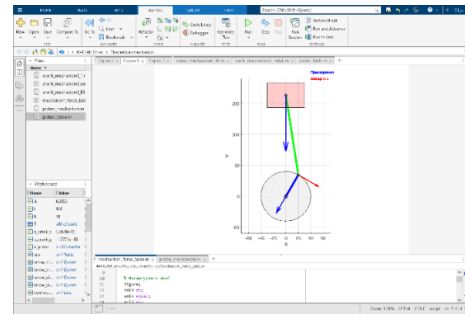


Fig. 2. Model of crank connecting rod mechanism in MATLAB program.

Education applicants are tasked with determining: piston position, linear velocity and acceleration of the piston, angular velocity and acceleration of the connecting rod. We do this by applying the formulas for determining kinematic characteristics:

$$x = R \cdot \cos\theta + \sqrt{L^2 - R^2 \cdot \sin^2\theta} \quad (1)$$

$$v_x = -R\omega\sin\theta \left(1 + \frac{\cos\theta}{\sqrt{1 - \left(\frac{R}{L}\right)^2 \sin^2\theta}} \right) \quad (2)$$

$$a_x = -R\omega^2\sin\theta \left(1 + \frac{1 - 2\sin^2\theta}{\sqrt{1 - \left(\frac{R}{L}\right)^2 \sin^2\theta}} \right) \quad (3)$$

$$\omega_s = \frac{v_x}{(L \cdot \cos\varphi)} \quad (4)$$

$$\varphi = \arcsin\left(\frac{R \cdot \sin\theta}{L}\right) \quad (5)$$

$$a_s = \frac{a_x \cdot L \cdot \cos\varphi - v_x^2 \cdot \sin\varphi}{L \cdot \cos^2\varphi} \quad (6)$$

When students gain enough experience with theoretical calculations, they move on to using software tools to analyse the mechanism. They learn engineering programs such as MATLAB that allow them to perform numerical differentiation and perform automated calculations (Fig. 3). This allows them to quickly analyse the motion of the mechanism under different parameters and build more accurate graphs and models. The use of software helps students to better understand complex processes and prepare for practical application of the acquired knowledge.

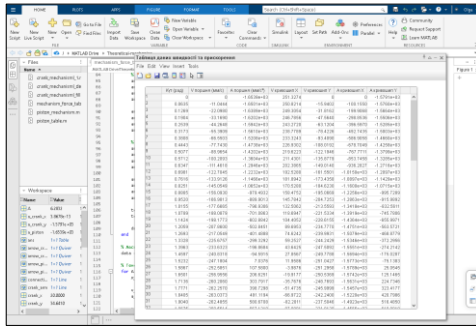


Fig. 3. Calculation of kinematic characteristics of crank connecting rod mechanism in MATLAB program.

In addition, they construct graphs illustrating the change in position, velocity and acceleration of the piston as a function of the crank angle (Figure 4). This allows a better understanding of the dynamics of the mechanism and the influence of its parameters on overall performance.

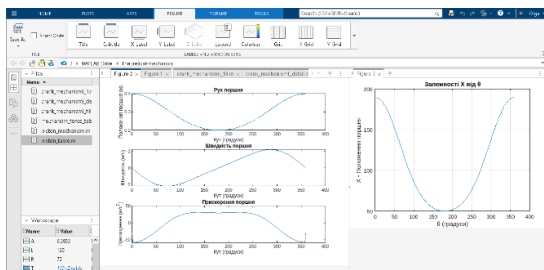


Fig. 4. Graphs of dependence of position, velocity and acceleration of the piston on the angle of rotation of the crank in MATLAB program.

This approach allows students to gradually expand their knowledge from simple calculations to complex mathematical modelling, providing a thorough understanding of the principles of crank mechanism operation.

III. RESULTS AND DISCUSSION

The pedagogical experiment was aimed at studying the effectiveness of innovative technologies in the learning process. The task of the pedagogical experiment was:

- To determine the level of students' mastering of the material when using traditional teaching methods.
- To develop and implement a set of innovative technologies for teaching the discipline.
- To compare the results of learning activity of students of the control and experimental groups.
- To evaluate the effectiveness of the implemented methods on the basis of testing, questionnaires and analysis of academic performance.

The pedagogical experiment involved 80 students of specialty 208 “Agroengineering” HEI “PSU”, distributed into two groups: control (40 students) and experimental (40 students). The experiment was conducted in two stages:

1. Stating stage – this stage was aimed at establishing the initial level of students' knowledge and their perception of the educational process. It was conducted: diagnostic

testing, which included a set of questions covering the basic concepts of theoretical mechanics. This made it possible to determine students' basic knowledge, their gaps and level of understanding of the subject before the experiment. Questionnaire survey of students to assess their attitude to the learning process, to identify the level of motivation, interest in the discipline and wishes on teaching methods. analysing the preliminary results of the training, which allowed to identify weaknesses in the assimilation of the material and outline ways to improve the teaching of the discipline.

2. Formative stage – implementation of innovative teaching methods in the experimental group, which included: use of specialized software for modeling mechanical processes (MATLAB, SolidWorks, AutoCAD, ANSYS) interactive lectures with multimedia accompaniment, involving the use of: animations and videos demonstrating mechanical principles in action; presentations with step-by-step explanations of complex processes; online simulators that allowed students to experiment with mechanical models in real time.

The comparative analysis of the results of the control (without the use of software) and experimental (innovative methods) groups showed high efficiency of using innovative techniques (Table 1):

TABLE 1. THE RESULTS OF COMPARATIVE ANALYSIS OF THE CONTROL GROUPS

Indicator	Control group	Experimental group
Average test score	65%	85%
Activity in classes	50%	90%
Motivation level	55%	88%
Satisfaction with the methodology	60%	92%
Success in accomplishing tasks	58%	89%
Time of learning new material	120 min.	80 min.
Execution of practical exercises	62%	91%

The introduction of multimedia materials such as interactive lectures, animations and videos has significantly improved the perception of the material. Students expressed positive feedback regarding the use of digital technology, noting that learning has become more interesting and accessible. Online simulators that allowed students to experiment with mechanical models, which contributed to a better understanding of real-world processes and patterns.

Optimization of learning time in the experimental group became possible due to a number of innovative approaches:

Application of adaptive learning platforms made it possible to individualize the learning process by providing students with materials appropriate to their current level of knowledge.

Visualization of complex processes through animations and interactive models contributed to accelerated understanding of theoretical aspects.

Modelling of real problems with the help of software (MATLAB) gave students the opportunity to apply theoretical knowledge in practice, which significantly reduced the time for learning new material.

A flexible testing system and instant feedback allowed students to quickly analyse their mistakes and re-learn difficult topics without having to wait for a long time for explanations from the instructor.

As a result, the time of material assimilation in the experimental group decreased from 120 minutes to 80 minutes, which indicates an increase in the effectiveness of training and better assimilation of knowledge. The success rate of tasks and practical exercises in the experimental group reached 91% against 62% in the control group. As a result, the students of the experimental group showed significantly better results in practical activities, which indicates an increase in their professional competencies and ability to apply knowledge in practice.

CONCLUSIONS

As a result, the use of digital educational technologies and interactive methods contributes to a deeper understanding of the material, the development of practical skills, an increase of 30% in the success rate in completing tasks, and even a 40% increase in group activity. The use of digital simulators, interactive platforms and adaptive online courses makes it possible to visualise complex mechanical processes, which facilitates the assimilation of theoretical principles, increases student motivation and helps to significantly reduce the average training time from 120 to 80 minutes. Unlike other studies, our work focuses on specific professional examples, allowing students to apply their knowledge to real-world agricultural engineering tasks. In addition to analysing the impact of digital technologies, we developed unique teaching modules in which each theoretical mechanics topic is supported by practical cases from the field of agricultural engineering. This allowed us to show students a direct link between theoretical knowledge and its application in professional activities, which significantly increased the level of engagement and efficiency of learning. The results of the study show that further expanding the use of digital educational technologies and adapting teaching methods to the modern requirements of engineering education are promising directions that will improve the quality of agro-engineering education, adapt it to the challenges of digital transformation and strengthen interdisciplinary links in the educational process.

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The Use of Digital Technologies in Teaching Culture and Foreign Languages to Technical University Students

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Abstract- The modern technological world is based on the interaction of professionals from different countries and cultures. To become full-fledged members of the global scientific, business and socio-cultural community, students of technical universities must not only acquire foreign languages of intercultural communication but also get an idea of the world culture in all its diversity. This study examines a technical university student's cultural and English language proficiency through a digital culture-related course for self-learning and flipped classroom activities. Culture is a complex and multifaceted concept that may be challenging for students to attain fully. Thus, a variety of representative cultural elements was selected for the course, which is comprised of three modules supporting the formation of competencies in such cultural spheres as social interaction, spiritual culture, and science and technology. The course was digitalized using audiovisual translation and implemented at Kharkiv National Automobile and Highway University in the 2022–2024 academic years. To study the effectiveness of the course, an experiment was conducted with the aim, firstly, to identify how the level of educational autonomy changed in the two groups of students: those who studied the course

using digital technologies (an experimental group) and those taught in a traditional format (a control group); and, secondly, to compare the level of assimilation of culture-related English language vocabulary in both groups. In this research, we applied both quantitative and qualitative methods to assess the results of the experimental work that proved the positive impact of the proposed approach on the student's linguistic and cultural competencies. The course contributes to raising intellectually, culturally, and multi-culturally developed citizens with a deep awareness of cultural values. It can be used as a template for creating innovative digital language learning resources.

Keywords- audiovisual translation, culture, foreign language, technical university students.

INTRODUCTION

In modern societies, many professionals lead highly mobile ways of life. They often go abroad, and can work for long periods of time in other countries where there is a demand for their skills. This is a new category of people, so-called “citizens of the world”, or people “beyond nations”. Having knowledge of a foreign language in the widest cultural context is essential for such professionals.

Online ISSN 2256-070X

<https://doi.org/10.17770/etr2025vol3.8512>

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The challenges of learning cultures and languages have become especially acute in recent times in the context of the “refugee crisis” in Europe, including that caused by the war in Ukraine. This current challenge is in addition to the inherent difficulties that immigrants face in adapting to new sociocultural environments.

In public debates and scientific discussions on immigration and migration for business or studies, cultural differences often occupy a central position as conflicts arise. Generally, attention is focused on finding ways to overcome obstacles that hinder acculturation as a process of the mutual influence of cultures, especially the perception of other people’s cultures.

In its broadest form, cultural adaptation is understood as a process of “immersion” of an individual into a new culture, the incremental mastering of its values, norms, and patterns of behavior [1].

In today’s reality the tight relationship between learning language and culture has become an axiom. In the contemporary context of globalization whereby many countries are no longer homogeneous, one must be ready to communicate with representatives of different cultures.

Multicultural societies abound throughout the world, however in order to become a full-fledged member of society, one must at least learn and tolerate – if not share – the values of other communities. Learning a foreign language is perhaps the most effective way of acculturation and adaptation to a new culture and its values.

However, at present cultural components in modern courses of foreign languages are vague and fragmented. Such courses certainly serve as an instrument of developing the learners’ communicative competencies, as they teach vocabulary, grammar, form skills of speaking, reading, listening, and writing, but culture is often represented in a scattered, chaotic, and scant manner.

The lack of cultural components in foreign language classes contributes to the poor adaptation of some technical university graduates to other nations’ values. It may also be a cause of low erudition, misinformed worldviews and lack of morality among university students.

We believe that a carefully designed, culturally rich foreign language educational course is necessary to enhance the skills required to navigate in a foreign land and culture. Such a course would increase the universality of cultural knowledge and values, and establish a baseline of core concepts that an educated prospective engineer should acquire.

Along with the selection of the culture-related content, an equally important task is the development of

appropriate methods that would combine teaching languages and culture. The most modern of these methods are related to advanced information technologies.

At present, especially due to the development of mobile technologies, education is experiencing a widespread transition from synchronous methods of teaching in the classroom to asynchronous ones, which allow students to study in any place and at any time convenient for them in a distance learning format.

In fact, we are witnessing how the global education system is being reformed and modernized as information provided by video, sound, text, and other data are conveyed by digital languages [2].

As stated by Díaz Cintas and Massidda, the increasing ubiquity of technology, along with globalization processes have made possible the rapid spread of information and messages of cultural character [3].

The wide dissemination of cultural information through the use of audiovisual translation (AVT) started in cinematography about a hundred years ago, and since then has been gaining ground in other areas, including education, and, in particular, teaching foreign languages (FL) [4]. The increasing availability and affordance of technology allow audiovisual products to be rapidly disseminated through television, computer, smartphones, tablets and any other digital devices equipped with a screen.

According to Chaume, AVT as an academic term includes both traditional and state-of-the-art linguistic and semiotic forms like subtitling, dubbing, respoken, audio-subtitling, voice-over, and fansubbing [5].

ATV is a kind of translation that involves the transfer of audiovisual texts either interlineally or interlingually. It involves the use of a multimedia electronic system for conveying messages, and an audiovisual text is created using such semiotic means as speech, image, music, etc., which are combined together to be shown on the screen. As follows from the name of this type of translation, it simultaneously affects two channels of communication: acoustic, through which verbal and paralinguistic information is transmitted; and visual, through which the perception of images and linguistic signs occurs.

Currently, audiovisual resources are a significant cumulative bank of materials for teaching foreign languages, which contains rich linguistic and cultural information [6].

At the same time the considerable potential of AVT in learning languages and cultures needs further exploration.

This research is aimed at

1) the substantiation of the relevance of culture in a foreign language education and assimilation of multiple aspects of culture in an adaptive learning course;

2) the development, digitalization (using audiovisual translation), and implementation of the course comprising modules that support the formation of competencies in various cultural spheres;

3) the study of the impact of the audiovisual course on the level of students' mastering the culture-related vocabulary and their autonomy in learning languages and culture.

MATERIALS AND METHODS

The effects of teaching FL and culture via AVT were compared with the results of a traditional in-person format in teaching English as a FL at the Department of Foreign Languages at Kharkiv National Automobile and Highway University.

Using a randomization selection process, an experimental group (EG) of 53 people and a control group (CG) of 54 people were gathered, both groups being nearly equal in terms of gender and age. The EG students studied a foreign language (English) course using the technology of learning language and culture via AVT. They were exposed to both in-class and out-of-class instructional materials, including mini audio-visual files uploaded on YouTube. The control group students were exposed to in-person class activities and instructional materials in a printed format. The participants of the study had one 90 minutes class per week during the 2022 – 2024 academic years.

To determine the cultural components to be taught in a foreign language course, we considered several views on the concept of culture and decided what it means to us.

The problem is that despite numerous attempts to come to a common understanding and interpretation of the concept of culture, there is no single commonly accepted definition [7], as culture is an all-embracing concept which can cover a great diversity of phenomena, from universal values to peculiar cultural expressions [8].

Culture is a complex and multi-faceted concept that is extraordinarily challenging for students to assimilate completely, so a careful selection of cultural elements that represent culture in its entire structural completeness was needed.

To determine the elements of culture to be selected for our course we used a model of culture which included three subsystems pointed out by Leavitt: technological, sociological, and ideological [9].

In our case technological culture is the use of scientific knowledge to solve practical engineering problems; sociological culture is associated with the

sphere of communication, in which we distinguished day-to-day social interactions and cross-cultural communication; ideological culture was treated as spiritual culture that includes arts and humanities.

Then, we specified the structure and the volume of cultural knowledge to be taught to students in a foreign language and developed a special three-module course aimed at familiarizing the learners with many significant cultural achievements and a cultural treasury that comprises:

1) social interaction;

2) spiritual heritage (including Historical periodization, modern history, World Wars, contemporary history, world economy, state, election, politics, world religions, art, painting, sculpture, music, literature, cinema, education, science, traditions, language, sport etc.);

3) science and technology.

Each module was divided into units that were presented in an audiovisual format and placed on YouTube as separate audiovisual files (we developed and placed about 200 videos), each lasting 20–25 minutes [10], and that were also available in a printed format.

The novelty and distinctive feature of this approach is that in the design of the course we extensively used a learner's mother tongue (MT) in contradiction to the use of only a FL, as proposed by Butzkamm and Caldwell [11].

For many years, a student's native language has been ignored as a resource in FL learning, and in some contexts has even been banned. However, this policy is not followed by most teachers, and the arguments for excluding the native language are not supported by research [12], [13].

The learner's own language has been "treated as a pariah" in almost all modern language teaching theories [14]. The approach "no MT, no printed word, as little "drill" as necessary, and, hopefully, instant participation in "real-life" activities is a recipe for submersion, not immersion" that calls for a fundamental rethinking of the FL methodology [11].

Krashen's Comprehension Hypothesis [15] states that we acquire language when we understand messages, when we understand what people tell us, and when we understand what we read. According to this Hypothesis the first language helps to make input more comprehensible as you can banish the learners' native language from the classroom, but you cannot banish it from their heads since it always dominates their minds.

The translingual or translanguage teaching, which means the switching from one language to another, is relatively new in education. It is an educational

technology that provides for the use of the learners' knowledge, skills and experience acquired in their MT for FL acquisition. As some authors state, this term also describes a language practice that involves a deliberate alternation between the language of input and output in the classroom [16].

In our course design, we used elements of translanguaging in the form of parallel translation when students were provided with bilingual recorded texts placed on the screen for out-of-class self-study.

The method of parallel translation whose efficiency is so far underestimated, have been used by almost all polyglots, i.e. people who manage to learn numerous languages by themselves [17].

Then the material was supposed to be drilled. Some methodologists are still skeptical about drilling though this method has been used by foreign language teachers for many years and, despite accusations of some monotony, has proven its efficiency, especially at the initial stages of language learning. The essence of the method lies in the multiple repeating of structures in order to bring them to automatism.

In our case, drilling provided students with intensive listening and speaking practice, presented correct pronunciation patterns; while repeating the words after the speaker on the video, and then listening to the model, the students immediately received feedback and could analyse their mistakes; and, perhaps most importantly, they got the opportunity to independently listen to and study the language material in a volume and at a pace appropriate for each individual student, which created a safe learning environment, allowed learners to feel secure and confident, thus making drilling an invaluable assistant in the memorization and atomization of language patterns [18].

So, the students imitate words and phrases they can hear and see, they repeat them as many times as necessary for sound memorization, thus independently honing phonetic and speaking skills and saving time for performing creative and problem tasks in the classroom.

When the material has been drilled by students on their own, it becomes possible to break away from the fixed text and use the new skills in practice. During off-line or on-line classes with a group, the self-learned material was used in new contexts interesting and useful for students. Our approach falls under the definition of the flipped classroom, i.e. a phenomenon that has become an integral part of blended learning due to the continuous digitalization of education.

As modern technologies develop, flipped learning is becoming increasingly popular in various fields of education, including foreign language teaching. This approach reverses the traditional components of the educational process, that means that students

independently prepare the material before coming to class, by watching and listening to videos recorded by the teacher or downloaded from the Internet in a ready form, and class time is devoted to the practical use of the material and solving higher-order problems to consolidate knowledge [19].

This is fundamentally different from the traditional approach, in which students first watch a video in the classroom, then the content comprehension is checked, and only then a discussion is organized. It is natural that, firstly, there is much less time left for discussion than in case of the flipped classroom, and, secondly, there are always students who do not manage to "catch" the material of the video from the first attempt in the classroom and they simply fall out of the educational process.

RESULTS AND DISCUSSION

The effectiveness of the proposed approach was assessed by such criteria as

- 1) students' autonomy in learning;
- 2) assimilation of culture-related vocabulary.

The criterion of autonomy in learning characterizes the focus of students on self-education and self-improvement in the field of language and culture studies, with such levels as autonomous, dependent, and indeterminate.

The so-called "autonomous" students are focused on self-education and self-development. They are characterized by a high degree of independence, showing such qualities as persistence, purposefulness, self-directedness, self-control, self-confidence, aspiration to work on their own. The "dependent" students are characterized by near absence of such qualities, and their educational activities mainly rely on their instructors and external incentives. "Indeterminate" students cannot be classified with certainty as being "autonomous" or "dependent", because they have approximately equally pronounced features of both types.

To diagnose the level of autonomy in order to place the students in one of the three groups, they were asked to answer the items of the questionnaire [20] though adapted to our purposes.

The questionnaire for identifying the style of learning consisted of 18 statements with which the testee might agree (+) or disagree (-). Students who scored 11 or above could be classified as "autonomous", while those who scored 7 or below could be classified as "dependent". Students with the score of 8, 9, 10 points were classified as "indeterminate".

We used a Likert scale which provided a range of responses to the question to what extent the students needed external stimula to study culture in the foreign

language via AVT. Additionally, we used the open-ended question which we consider a very attractive tool to provide a sincere and honest personal comment: please, indicate areas for improvement in the teaching of FL and culture with the use of audiovisual technologies.

The data shown in Table I demonstrate to what extent the described approach affected the students' autonomy in learning which is considered a very desired result of education.

TABLE I TRENDS IN THE DEVELOPMENT OF LEARNING AUTONOMY (%)

The learning style	Group			
	E (53)		C (54)	
	Before experiment	After experiment	Ascertaining data	Control data
Autonomous	43.5	72.4	45.0	57.7
Dependent	41.3	17.0	44.3	31.2
Indeterminate	15.2	10.6	10.7	11.1

During the second academic year under consideration, when the students were more or less prepared for events held in English beyond the classroom, they were quite regularly involved in various kinds of cultural practices in the English language, namely: contests of students' essays, round tables, conferences, contests for the best translation of English prose and poetry, an English language Olympiad at the University and beyond.

The dynamics in the number of participating students from both, the EG and CG groups, presented in Fig. 1. clearly shows a much greater percentage of the EG students involved in these events.

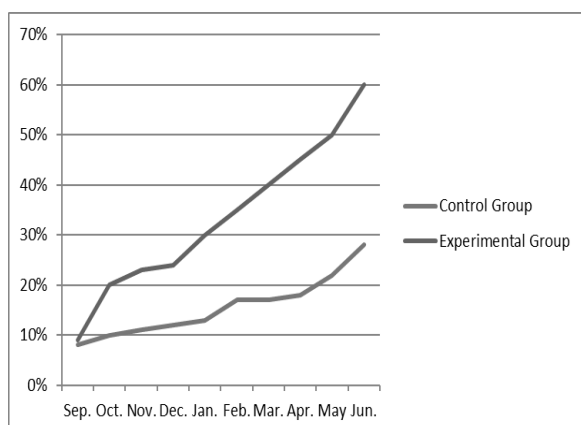


Fig. 1. Dynamics of the students' involvement in cultural activities.

A second criterion of efficiency of learning language and culture was the level of vocabulary assimilation.

High correlations between vocabulary assimilation and other parameters of foreign language knowledge and skills were found long ago. A large vocabulary is undoubtedly considered one of the most important indicators of developed foreign language communicative competence.

Students were given a performance test consisting of a pre-test and post-test developed on the basis of the course content. This was used to evaluate the learners' proficiency in using culture-related vocabulary.

The pre-test and post-test consisted of multiple-choice questions, fill-in-the-blank items, true-false questions and sentences to write using provided words.

We also monitored changes in vocabulary using a complementing technique. Students were given samples of texts with missing culture-related words and were asked to fill the gaps. Some examples of tests to the module "Spiritual heritage" are given below.

(Unit: The 21st century)

Fill in the text with appropriate words from the list:

- renewable sources of energy;
- dwindling;
- uprisings;
- nuclear energy;
- integration;
- changes;
- threats.

The 21st century has been marked by growing economic globalization and (1)... . Expansion of communications with mobile phones and the Internet has caused fundamental (2)... in business, politics, and individuals' personal lives. The Arab Spring, a revolutionary wave of (3)... in Africa and Asia led to a resurgence of authoritarianism and the advent of reactionary groups like the Islamic State. A need for safe, reliable energy supplies has spurred the development of (4)... , chiefly solar and wind energy, in place of the (5) ... and carbon-based energy. So far the century has seen many global (6)... including nuclear proliferation, global climate change, air and water pollution, deforestation, overpopulation, the (7)... of natural resources worldwide.

(Unit: Election)

Choose the correct answer to the following question:

Why is the secret ballot considered crucial in most free and fair elections?

- It limits the effectiveness of intimidation.
- It increases openness and accountability.
- It gives people the right to select their own government.

(Unit: Religion)

Match the halves of the sentences:

- | | |
|---|--|
| 1. A religion is a set of beliefs | a. or certain times of a person's life. |
| 2. In many religions, one of the main beliefs is that | b. synagogues. |
| 3. In each religion people often have rituals for certain times of the year | c. mosques. |
| 4. In Judaism, temples are called | d. churches |
| 5. In Christianity, they are called | e. that is passionately held by a group of people. |
| 6. In Islam, they are called | f. are called agnostics |
| 7. People who say that there is no evidence of god | g. there is a "deity" (or god) who is a great creator spirit |

(Unit: Sculpture)

Answer the questions:

1. What materials are considered traditional for sculpture?
2. What are the major techniques in sculpture?
3. What material for sculpture survives better than others?
4. What are the most famous statues in the history of sculpture? etc.

The measurements were carried out on an ordinal scale with L gradations. In our case, three levels of knowledge were identified (L = 3): low (knowledge of only certain concepts related to culture; the number of completed tasks is less than 60 %), medium (limited knowledge of vocabulary; the number of completed tasks is 60 – 74 %), high (students are fluent in concepts, lexical units and phrases in different socio-cultural areas; the number of completed tasks is more than 75 %).

The results presented in Fig. 2, show that in the experimental group where culture-related vocabulary was learnt via AVT, the indicators are much higher than those in the groups, where the technology was not used.

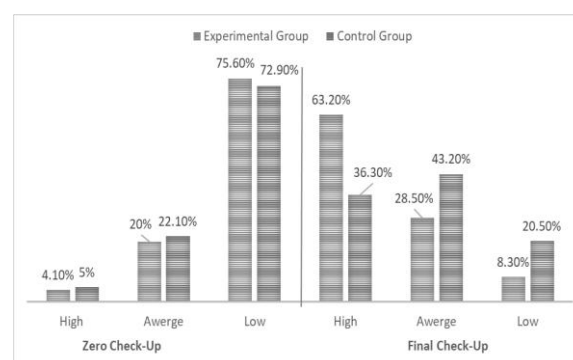


Fig. 2. Culture-related vocabulary assimilation rates

The data analysis tools had a software implementation in the form of a computer program “Statistics in Pedagogy”, which showed more prominent positive changes in the statistical data of the experimental group compared to the control sample by the test of significance [21].

Thus, the effectiveness of the developed approach is demonstrated by a significant positive change in the autonomy of the EG students and the quality of their culture-related vocabulary.

We fully agree with the authors [3] that different forms of audiovisual translation products continue to cross linguistic borders, having more and more influence on viewers.

This type of a bilingual course can be developed for learning any language. The most important result is that the cultural content is developed to be used in variations with any other languages depending on the demand of learners and market. This approach can be especially useful for the countries that have to deal with the issues of large-scale immigration and/or receiving many international students, as it offers people opportunities to learn languages in a wide cultural context on their own.

Our approach proposes the following innovative elements. The first innovative element is the integrated learning of language and culture, whereby culture includes thoroughly selected cultural components (as opposed to the chaotic representation of cultures that currently appears in modern text-books).

The second innovative element consists of utilising the MT in acquiring the FL. The third innovative element is the use of AVT for learners outside educational institutions to enhance their language proficiency.

The flipped classroom approach facilitates language acquisition by providing students with an unlimited access to electronic resources and helps them become autonomous learners, free from the constraints of social

situations. In modern literature, this is called adaptive learning.

There is a growing global recognition that a one-size-fits-all approach to learning is not sufficient to meet the needs of students or society as a whole. To address this problem, many countries such as Australia, Canada, Denmark, France, Germany, the UK, New Zealand and the US are increasingly turning to personalized learning to meet the diverse needs of students.

While there are many definitions of this new phenomenon, personalized learning is generally viewed as an educational approach in which the learning experience is customized to each student to meet their needs and to take into account their strengths, skills, experiences and interests [22].

The purpose of the adaptive technology in the higher education is to teach students to independently acquire knowledge with maximum adaptation of learning to the individual characteristics of students.

Adaptive personalized learning expands educational opportunities for students without significant material costs. This technology promises to make high-quality, low-cost education available to an unlimited number of people.

Modern advances in information technology and cognitive psychology have led to the development of adaptive learning systems that allow FL learners to increase their vocabulary and improve their language skills more effectively. A variety of adaptive models and applications are being developed that use software to teach vocabulary and pronunciation in real time with assessment of the accuracy of students' pronunciation [23].

A new stage in the development of adaptive technologies for language learning has started with the emergence of mobile learning tools which makes education available anywhere and at any time. The peculiarity of mobile devices is the ease of use, reasonable price for students and the ability to communicate via the Internet or mobile networks, which contributes to the emergence and development of various FL teaching methods [24].

The development of an autonomous learner is, of course, the aim of all educators – not to produce masters but to allow people to improve their education and to continue to grow intellectually.

The described course is only one example of several opportunities for language acquisition that AVT offers. The limitation of the proposed method is that it can only be used in monolingual classes where the entire group of students are native speakers of the same mother tongue. However, such classes are commonplace in the traditional education system of most countries, so

anywhere in the world any teacher can use the already developed cultural content in English for their students, no matter what language they speak.

CONCLUSIONS

We believe that AVT has a big potential for teaching foreign languages and culture though needs to be further explored.

As Chaume puts it, the inventory of audiovisual translation modes is in no case closed, and indeed it is bound to grow and change as new audiovisual formats, and technological advances and audience tastes evolve and change [4]. As educators, we must also evolve and change alongside the new technologies that emerge.

Undoubtedly, it is imperative for foreigners who choose to work or study abroad, immigrate or establish business contacts with locals to at least learn the cultural values of another country, if not adopt them. Learning a foreign language can be a powerful practical instrument of assimilation.

As it may be challenging for students to fully learn a complex and multi-faceted concept such as culture, we developed, digitalized, and implemented a special bilingual course aimed at familiarizing students with important cultural achievements and cultural treasures of the world. The course comprises three modules that support the development of competences in various areas of culture: social interaction; spiritual heritage, and science and technology.

The distinctive feature of this course consists of utilizing the potential of the mother tongue and ATV in acquiring a foreign language. This course has proved to be effective for distance learning during the Covid-19 quarantine and, most importantly, a wartime period in Ukraine. It can be used as a template for developing bilingual courses for learning any language.

Our research reveals that doing so not only improves university students' language proficiency, but also contributes to raising intellectually, culturally, and multi-culturally developed citizens with a deep awareness of cultural values. This study proves that despite challenges, using AVT in teaching foreign languages and culture had significant positive effects on students' language competence, problem-solving skills, critical thinking, and learning motivation.

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Development of Information Technology Competence in Pre-school and Pre-primary School Teachers During the Education Process

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Abstract—This article discusses the significance of digital technologies in education and how they should be integrated into the learning process. While technologies can serve as valuable tools in education, their effective application in working with preschool and pre-primary children poses challenges due to children's developmental characteristics, specific needs, and educators' competencies in integrating information technologies (IT) into the learning process. The study aims to assess the expression of IT competence among preschool and pre-primary educators. The research methods include scientific literature and document analysis, a written survey (questionnaire), and both quantitative and qualitative data analysis. The analysis of scientific literature and documents highlights that preschool and pre-primary educators' IT competence encompasses key abilities such as digital content creation, digital communication, safety, and problem-solving. Essential skills include using IT applications and digital tools (computers, tablets, interactive whiteboards) to enhance children's artistic expression and writing skills, as well as understanding and effectively communicating digital terminology to children. The study also identifies opportunities for integrating IT into the learning process, such as educational games, video content viewing, online collaboration, information retrieval, content creation, and voice recording exploration. Empirical findings reveal that most respondents can define IT competence and recognize its increasing importance. Interactive floors and interactive whiteboards are the most commonly used digital tools in early childhood education. However, educators often face challenges such as a lack of IT resources, slow internet connectivity, limited time for IT use, and insufficient knowledge or time for professional development. IT is frequently used for exploring e-books, fairy tales, maps, educational videos, and online information searches. However, tools such as voice recorders, printers, and cameras are rarely utilized, and activities such as creating

presentations, illustrations, remote communication, and playing educational games remain infrequent.

Keywords — IT competence, digital literacy, preschool and pre-primary educator, information technology.

I. INTRODUCTION

A. Relevance of the topic.

The field of information technology is rapidly evolving, requiring continuous adaptation to new developments [1]. Rodzevičiūtė [2] highlights that transformations within the education system also influence the role of educators. In modern education, the competencies, abilities, and IT skills of educators have become crucial factors in the learning process [3]. Digital technologies play a key role in enhancing the efficiency of the educational process and providing access to new resources, fostering the development of children's critical thinking, independence, and collaboration skills [4]. Additionally, the incorporation of IT in education contributes to the overall improvement of teaching and learning processes, making education more engaging and effective [5]. Digital literacy competence benefits children by enabling them to keep up with innovations and apply IT appropriately from an early age, potentially offering greater advantages than traditional teaching methods [6]. Advancements in IT provide students in educational institutions with broader learning opportunities [7]. The use of IT in educational institutions enhances children's digital literacy, increases motivation, and improves learning outcomes [8]. The educational significance of children's computer culture is linked to the contexts shaping their experiences within different domains of digital culture — gaming, informational, and communicative [9]. Through these experiences, adults gain insight into children's digital world, understanding its value

Online ISSN 2256-070X

<https://doi.org/10.17770/etr2025vol3.8558>

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for child development. This perspective helps educators adopt new roles, such as consultants, facilitators, and mediators, while recognizing children as active creators of digital culture [10]. Many scholars emphasize the importance of IT in education, contributing to the understanding of its meaningful integration across various subjects [11]. Research also explores the necessity of IT competence for professional careers [12], the impact of modern learning tools on 5–6-year-old children's play and the significance of IT in education [13, 14]. Studies further examine international experiences in implementing ICT in education and pedagogical approaches to organizing lessons with interactive teaching tools, such as the "ActivInspire" system [16].

Although technology can be a valuable tool in the learning process, its effective use for preschool and pre-primary children presents challenges due to their developmental characteristics and needs. The application of IT in early childhood education depends on educators' digital literacy and their ability to adapt technological tools to children's developmental stages. IT can be utilized in various preschool activities, serving as a supportive tool in music lessons, games, artistic tasks, early numeracy learning, and other educational contexts [6].

B. Research problem

Various documents highlight the significance of digital technologies in education and how they should be implemented in educational institutions. However, as years go by, IT is rapidly advancing, with new tools and various programs emerging. These changes create a need to ascertain how educators today are practically applying information technologies in the children's educational process.

While technology is a valuable educational tool, its use in preschool and pre-primary education presents challenges due to children's developmental needs.

C. Research object

The expression of information technology competencies among preschool and pre-primary educators in the educational process.

D. Research aim

To ascertain the expression of information technology competencies among preschool and pre-primary educators in the educational process.

E. Research objectives:

1. To discuss the information technology competencies of preschool and pre-primary educators and the possibilities for applying information technologies in the children's educational process.

2. To determine how preschool and pre-primary educators practically apply information technologies in the educational process.

F. Research methods:

Analysis of scientific literature and documents, written surveys, quantitative and qualitative data analysis.

It is evident that, over time and with the rapid advancement of new technologies, the priority directions and objectives of various fields, including education, are changing. The fast-paced world drives the need for innovative learning methods, while the application of information technology (IT) is accelerating. The expansion of modern information technologies is particularly relevant in the educational process. Educational institutions are rapidly integrating various IT tools, creating opportunities for changes in the educational process, facilitating the implementation of open learning policies, enhancing the effectiveness of distance education, and ensuring greater flexibility in learning organization [8].

Information technologies play an exceptionally important role in today's world, permeating almost all aspects of an individual's life, including work, learning, home life, and social interactions. The greatest value of information technologies lies not in the technologies themselves but in the new opportunities they create. In this rapidly changing era, educators should remain flexible, embrace emerging innovations, and integrate them into the educational process [16]. The evolution of information technologies will continue to reshape the education system, redefine the role of the teacher, and transform learning environments [17].

Global transformations necessitate continuous professional development for educators, encouraging them to enhance existing competencies and acquire new ones. Ensuring a successful teaching and learning process now requires more than just professional expertise; increasing emphasis is placed on teachers' ability to prepare students for life, including social skills and career education. Consequently, new teaching methods, assessment techniques, and evolving teacher roles necessitate an adaptive approach to education [20].

Children of Generation Alpha were born into a world where information technologies are highly developed. This generation has a strong connection to IT, demonstrating remarkable proficiency in their use. Compared to Generation Z, Generation Alpha will take the next step in utilizing technology. Furthermore, virtual spaces and online learning will become even more integral to their educational experience [1, 21].

The evolving roles of educators in the modern education system are inseparable from new professional competencies related to the use of information technologies, both in their own learning and in the instruction of students [14].

The Description of Teacher and Student Support Specialist Competencies (2023) [22] identifies four key areas of competencies relevant to educators: professional behavior, collaborative engagement, emotional-motivational, and cognitive competencies. Information technology competence is classified as a component of the cognitive domain.

In today's context, information technology competence is highly relevant, making it essential to understand its key components. The Competency Development Framework

[3] defines digital competence as “the motivation and ability to use digital technologies to perform tasks, learn, solve problems, work, communicate, collaborate, manage information, and create and share digital content effectively, appropriately, safely, critically, independently, and ethically.” The Teacher and Student Support Specialist Competency Framework [22] further specifies the core components of information technology competence: digital content, digital communication, digital safety, and problem-solving. These components, along with their descriptions, are presented in Table I.

TABLE I. COMPONENTS OF INFORMATION TECHNOLOGY COMPETENCIES AND THEIR CONTENT

IT Competency Components	Content of IT Competency Components
Digital Content	Creates and works with digital content in various forms and formats, including searching, filtering (selecting), analyzing, and critically evaluating digital content. Manages, restructures, integrates, and automates content processing. Explains copyright and licensing regulations related to digital content.
Digital Communication	Communicates and collaborates using digital technologies, including social and civic engagement in the digital space. Adheres to universally recognized network etiquette, manages digital identity, protects personal and others' reputations online, and handles information presented through digital means.
Digital Safety	Uses digital technologies securely, protects personal data and privacy in the digital environment, ensures the environmentally responsible use of digital technologies, and safely operates digital devices and information systems.
Problem Solving	Creatively utilizes digital technologies to solve problems, including addressing technical and technological issues in computing (information) systems, critically evaluating possible solutions, selecting appropriate digital technologies, and assessing one's digital competence while identifying skill gaps.

Source: Compiled by the authors of the study based on the Competency Development Description, 2022

It is essential to recognize that early childhood and pre-primary education teachers should integrate information technologies into the learning process, as outlined in the *General Pre-Primary Education Program* (2022) [23]. Consequently, educators in these levels must be proficient in IT terminology, use it effectively, and be able to convey information to children. By utilizing IT tools and software, teachers should foster children's numeracy skills and artistic expression. They must also understand the operational principles of various digital technologies, such as cameras, computers, tablets, and interactive whiteboards, and be competent in their application. Therefore, the development of IT competencies among educators presents a significant challenge in early childhood education.

When addressing the integration of information technologies in pre-school education, it is important to consider whether pre-school and pre-primary children can develop IT competencies and, if so, at what level. Recent scientific advances, international recommendations, and national strategies — such as Lithuania 2030 and the Agreement on Lithuanian Education Policy (2021–2030) — have influenced the expansion of competencies in education. In response to these developments, the 2023 revision of the General Pre-Primary Education Program introduced digital competence as one of the key competency areas.

In pre-school education, digital competence is understood as the ability to use digital technologies effectively, safely, critically, and ethically for learning, problem-solving, communication, collaboration, information management, and content creation. It encompasses four main components: digital content creation, digital communication, digital safety, and problem-solving.

The General Pre-Primary Education Program [23] emphasizes that, through play and participation in various activities, children gradually learn to use digital devices and technologies responsibly, search for information, create basic digital content (such as drawings or short videos), and engage in digital communication and collaboration. Thus, in pre-school education, IT competence refers to the initial and developmentally appropriate use of digital technologies, supporting the gradual acquisition of digital literacy skills from an early age.

The application of information technologies in the educational process and the opportunities they provide have the potential to address emerging societal development challenges. As a result, a significant increase in the implementation and expansion of information technologies in education is currently being observed [25]. The widespread availability of IT offers new ways to enhance learning [26].

In the past, information exchange between teachers and parents primarily occurred through verbal communication. However, in contemporary times, electronic communication has become increasingly prevalent. The use of electronic gradebooks aims to facilitate teachers' work, ensure the timely dissemination of useful information to students and their parents, and actively engage them in the school community's activities and continuous dialogue, thereby enhancing the quality of children's education [27].

Modern parents are more inclined to collaborate with educators through information technologies rather than face-to-face interactions. Advancements in information technologies encourage communication between parents and teachers through electronic mail, mobile phones, websites, social networks, and messaging applications [28].

Educators also incorporate information technologies into the learning process, providing numerous benefits to

children. The *Guidelines for the Development of Informatics and Information Technology Education 2014–2020* [24] highlight that children are introduced to information technologies even before they start school. The guidelines also indicate that recent advancements in IT have led to increased opportunities and a broader application of technologies for personal needs (*Guidelines for the Development of Informatics and Information Technology Education 2014–2020*) [24].

The *General Pre-Primary Education Program* [23] states that through play and participation in various activities, children learn to use digital devices, tools, and technologies responsibly, safely, and ethically while engaging in digital communication. By utilizing available digital technologies—such as tablets, smartphones, interactive screens, and educational applications children explore digital content, search for information, draw, create, engage in educational games, and investigate their surroundings (e.g., maps, nearby objects, and natural phenomena). Additionally, they begin to develop basic digital content, such as music and video recordings, and experiment with technology for communication and collaboration while sharing their experiences. Furthermore, the program highlights that children have the opportunity to prepare and present brief reports, illustrate narratives using information technologies, and use applications for step counting and other interactive activities.

TABLE II. POSSIBILITIES OF USING INFORMATION TECHNOLOGIES IN CHILDREN'S EDUCATIONAL PROCESS

Areas of Learning	Methods Utilizing Information Technologies
Digital Content Creation and Exploration	Creation of short messages and illustrations [29].
	Basic digital content creation e.g., video recordings [23].
	Use of a camera to capture moments for experimentation [10, 30].
	Exploration of Printer Capabilities [30, 23].
Learning and Information Research on the Internet	Playing educational games [29].
	Exploration of electronic fairy tale books [29].
	Listening to and watching narrated fairy tales online [30].
	Investigating various maps, objects, and phenomena online [31].
Audio Recording and Analysis	Conducting online information searches [30, 3].
	Utilizing a voice recorder to explore voice recording capabilities [22].
Communication and Collaboration	Remote communication and collaboration, e.g., during various projects [23].

Source: Compiled by the authors of the study based on the analyzed scientific literature and documents

Thus, there are numerous opportunities for educators to integrate information technologies into their teaching practices. Among these are the use of electronic gradebooks, email communication, and various other IT

applications in the children's learning and development process.

II. MATERIALS AND METHODS

The empirical research was conducted in March 2024. The aim of this study was to determine how preschool and pre-primary education teachers practically apply information technologies in the educational process.

To assess the expression of information technology competencies among preschool and pre-primary education teachers in the educational process, a quantitative research approach was employed, using a written survey as the primary method. The written survey is one of the most commonly used data collection methods in sociological research [32]. This method was chosen due to its several advantages: respondents could independently select the time and place for completing the survey, the response time was less constrained, and participants had the opportunity to carefully consider their answers. Furthermore, the method ensured greater privacy, eliminating any discomfort that might arise in face-to-face interviews. Selecting a written survey increased the likelihood of receiving more open and sincere responses [33].

To achieve the research objective, a questionnaire survey was conducted. The questionnaire was hosted on the online platform www.apklausa.lt. It consisted of 15 questions: 11 closed-ended questions with predefined response options—allowing respondents to select one or multiple answers—and 4 open-ended questions, enabling respondents to express their opinions. The questions were formulated to collect data essential for the study, primarily based on a review of scientific literature. The key research questions aimed to gather data on the following aspects: the information technology competencies that preschool and pre-primary education teachers perceive themselves to have; the extent to which they integrate information technologies into the educational process; and the perceived lack of information technology resources in preschool education institutions.

The survey targeted teachers working with preschool and pre-primary-aged children. The study involved preschool and pre-primary education teachers from educational institutions in Alytus city and district municipalities. According to data from the 2022–2023 academic year, there are approximately 481 preschool educators in Alytus city and district. The sample size was determined using standard statistical parameters, with a confidence level set at 95% and a margin of error of $\pm 7\%$. Statistical analysis indicated that a minimum sample of 145 respondents would provide a reliable representation of the total educator population.

A total of 145 questionnaires were distributed, and 102 completed responses were received, resulting in a 70.3% response rate. In social science research methodology, this response rate is considered sufficient to ensure data representativeness [36]. The achieved sample size provided statistically valid parameters to meet the study's research objectives.

The study adhered to all ethical principles necessary to ensure research integrity. Respect for confidentiality and anonymity was maintained throughout the process. The questionnaire included a statement explaining that respondents' answers would be used only in an aggregated form and that no personal data would be disclosed. The most fundamental ethical principle of honesty was upheld throughout the study, ensuring that all presented data were accurate and not manipulated [33].

III. RESULTS AND DISCUSSION

The study aimed to determine whether preschool and pre-primary educators are familiar with various digital technology terminologies, use them in practice, and can effectively convey related information to children. Additionally, it sought to assess their ability to develop children's writing skills through information technology tools and various software programs, employ digital applications to enhance children's artistic expression, and understand as well as operate different digital devices such as cameras, computers, tablets, and interactive whiteboards.

Respondents were asked to indicate their level of agreement with the provided statements. The research findings revealed that the majority of surveyed educators (76.7%) agreed or strongly agreed with statements regarding their knowledge and use of digital technology terminology. Furthermore, 78.8% demonstrated an understanding of and the ability to operate computers, tablets, and interactive whiteboards, indicating a high level of familiarity with information technology.

According to the *Description of Preschool Children's Achievements* (2016), educators must possess a strong understanding of digital technology terminology and be proficient in using various digital tools, such as computers, tablets, and interactive whiteboards, to effectively support children's skill development. Moreover, educators need to be knowledgeable about programs designed for developing writing skills and enhancing artistic competencies, as well as be proficient in their application.

The study results confirm that educators possess the necessary competencies to successfully integrate information technologies into the educational process. Specifically, 64.3% of respondents reported using information technology tools to develop children's writing skills, while 64% employed IT applications to support and enhance children's artistic expression.

The research also sought to evaluate the specific competencies of preschool and pre-primary educators in utilizing information technologies. Respondents were asked to assess their proficiency in performing the following tasks: *communicating using information technologies, collaborating through information technologies, utilizing modern technologies to create digital content (e.g., video recordings), practicing safe behavior in digital environments, protecting sensitive digital content and ensuring the confidentiality of children's information and achievements*. Educators were

required to indicate their level of proficiency in these areas using the following scale: *"Highly proficient," "Proficient," "Neither proficient nor unproficient," "Not proficient," "Completely not proficient."*

The analysis of the study results suggests that the majority of surveyed educators possess digital literacy competencies. Respondents' answers indicate that nearly all educators are capable of communicating, collaborating, and performing various tasks using information and communication technologies (ICT). Specifically, 39.8% of respondents reported excellent communication skills through ICT, while 58.2% indicated effective communication abilities, with no significant difficulties observed in this area. Collaboration via ICT was reported as excellent by 39.2% and proficient by 46.4% of respondents, with none indicating difficulties. Additionally, 84% of respondents demonstrated proficiency in utilizing modern technologies and creating digital content, while only 4.1% encountered certain challenges. Furthermore, 88.6% of educators reported competency in safe online behavior, with no respondents indicating a complete lack of ability in this area. A total of 87.2% stated that they could effectively protect confidential information and sensitive content. These results align with the requirements outlined in the *Description of Teacher Professional Competencies* (2021) [3], which specifies that a digitally literate educator must be capable of communication, digital content creation, safe online practices, and critical evaluation of media content. Thus, the surveyed educators demonstrate strong readiness in utilizing ICT and are well-prepared to impart these skills to their students.

Another key objective of the study was to examine the opportunities preschool and pre-primary educators provide for children to engage with ICT. Educators were asked to indicate how frequently they enable children to use ICT in the learning process.

Survey results indicate that children most commonly engage with ICT by listening to and watching narrated fairy tales online (52.2%), exploring maps and various phenomena (82.6%), searching for information on the internet, and watching educational videos (69.6%). Less frequently used activities include exploring voice recorders (34.8%), utilizing printer functions (39.1%), and using digital cameras for capturing moments (30.4%). Additionally, children are less likely to create short presentations and illustrations, communicate and collaborate remotely (e.g., by participating in projects), or play educational games online.

The only activity with an evenly distributed response pattern was the creation of simple digital content (e.g., video recordings). Some respondents reported providing this opportunity to children quite frequently, while others indicated that children do not engage in such activities at all.

An open-ended survey question sought to identify the ICT tools used by preschool and pre-primary educators in the learning process: *"What ICT tools do you use in early*

childhood education?" The responses from 102 educators revealed that interactive whiteboards are the most frequently used tool (68.6%), followed by computers (44.1%). A smaller proportion of respondents reported using interactive floors (21.6%), mobile phones (20.6%), and tablets (15.7%). Projectors were used infrequently (11.8%), while smart robots were mentioned by only 2.0% of respondents.

The analysis suggests that educators increasingly integrate computers into the learning process, with interactive whiteboards being the most popular tool. In contrast, projectors, smart robots, and printers are used very rarely or not mentioned at all, which may indicate lower demand or limited availability of these technologies.

Educators were also asked to identify ICT shortages in their institutions: *"What ICT tools are lacking in your institution?"*

Survey results indicate that interactive whiteboards (26.5%) and tablets (25.5%) were the most frequently mentioned shortages. Some respondents also pointed to a lack of interactive floors (12.7%). A smaller proportion (6.9%) indicated a need for better computers, while only a few (2.0%) noted a shortage of printers.

A notable 24.5% of respondents stated that their institution currently has sufficient ICT resources. However, many educators expressed a desire for increased access to ICT tools, not only within the institution but also in each classroom, ensuring at least one device per group.

The findings suggest that while some educators do not experience a shortage of ICT tools, many recognize the growing need for interactive whiteboards and tablets in the learning process. Additionally, a number of respondents highlighted the importance of making ICT tools more accessible to children in their daily activities.

When asked about the challenges they face in integrating ICT into early childhood education (*"What difficulties do you encounter when using ICT in early childhood education?"*), responses revealed that 23.5% of educators experience no difficulties in applying ICT. However, 22.5% reported a lack of knowledge, training, or practical examples of ICT application. A smaller proportion (11.8%) mentioned time constraints, and a very small percentage (6.9%) cited occasional poor internet connectivity in their institutions.

The survey results indicate that while some educators face no difficulties, a significant proportion perceive a lack of training and practical guidance, emphasizing the need to strengthen their digital competencies. Additionally, time constraints and technical issues, such as weak internet connectivity, may hinder the effective use of ICT in education. These findings suggest that successful ICT integration requires not only better equipment but also continuous methodological and technical support for educators.

To understand how educators could improve their ICT skills, the survey included the question: *"In your opinion,*

what would help educators gain more knowledge about using ICT?"

The responses indicate that educators highly value opportunities to acquire additional ICT knowledge. The majority (38%) expressed a preference for participating in institution-based training, online courses, digital literacy improvement programs, or knowledge-sharing sessions with colleagues. A significantly smaller proportion (7%) indicated interest in formal ICT studies.

The findings suggest that educators are motivated to enhance their ICT competencies, with the most preferred learning methods being in-house training, remote learning courses, and digital literacy programs. This indicates a strong preference for practical and accessible learning opportunities. Additionally, the low preference for formal ICT studies suggests that educators favor short-term, immediately applicable learning formats over long-term academic programs.

IV. CONCLUSIONS

1. The analysis of scientific literature and documents reveals that the rapidly changing pace of life fosters the integration of information technologies into children's education. Consequently, educators must continuously develop their digital competencies, which have become an integral part of their professional activities.

IT competency encompasses not only digital content creation, communication, and ensuring cybersecurity but also problem-solving and the application of various technological tools, such as computers, interactive whiteboards, and tablets, for educational purposes.

To effectively integrate IT into the learning process, educators should utilize educational games, video materials, e-books, project-based collaboration, information retrieval, and the creation of basic digital content.

2. The results of the empirical study confirm that educators recognize the importance of IT competency — most acknowledge the significance of digital skills and agree that this competency is becoming increasingly relevant in the educational process.

The most frequently used tools for children's learning are interactive whiteboards and interactive floors; however, educators face various challenges, including a lack of IT resources, slow internet connectivity, limited usage time, and a shortage of knowledge and time.

It is observed that IT applications in the educational process are diverse — educators primarily use technology for interactive activities, such as reading e-books, watching video materials, and searching for information online.

However, certain tools, such as voice recorders, cameras, and printers, are used less frequently in the learning process. Additionally, digital content creation, remote collaboration, and the use of online educational games remain relatively underutilized.

The study highlights the growing recognition of IT's importance in education and underscores the need to enhance access to both technological resources and training opportunities.

3. Based on the identified challenges and needs, the following recommendations are proposed to enhance IT integration in early childhood education:

For the Education Departments of Alytus City and Alytus District Municipalities: Conduct a comprehensive needs assessment of IT resources across municipal educational institutions to identify and address existing resource gaps. Develop inter-institutional collaboration programs to facilitate the sharing of IT resources and best practices among preschools.

For Pre-school Institutions: Implement systematic professional development programs that focus on practical IT skills and their pedagogical applications. Establish communities of practice where IT-enthusiast educators can mentor their colleagues and share innovative approaches. Create structured feedback mechanisms to monitor the challenges and successes of IT implementation.

For Teacher Training Institutions (Professional Development Center of Kaunas Kolegija Higher Education Institution, Alytus Division): Organize thematic and practical training programs for preschool and pre-primary education teachers. These programs should focus on developing both digital competencies and pedagogical strategies for using technology in early childhood education.

These recommendations aim to create a sustainable ecosystem for developing digital competencies, addressing both infrastructural needs and pedagogical skills, while aligning with national education strategies and the evolving demands of 21st-century early childhood education.

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Preparing Students to Use Virtual Travel to Develop Preschoolers' Cognitive Interest

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Abstract—The modern educational space is undergoing significant changes under the influence of digital technologies, which open up new opportunities for teaching and upbringing of children. One of the innovative means of developing the cognitive interest of preschool children is the use of virtual journeys, which allow to broaden the worldview, stimulate curiosity and intensify educational and cognitive activities. The article deals with theoretical and practical aspects of preparing students for the use of virtual travel. The importance of digital technologies in preschool education, their impact on the formation of curiosity and motivation to learn about the world around us is analysed. The key methodological aspects of preparing future teachers for the implementation of virtual excursions, including the choice of content, integration with the educational programme and creation of an interactive educational environment are outlined. Attention is focused on the importance of developing students' digital competence for the effective use of modern educational resources in working with preschool children. An experimental study was conducted, the respondents of which were 67 2nd year students of the bachelor's degree in speciality 012 Preschool Education of Vinnytsia Mykhailo Kotsiubynskyi State Pedagogical University, studying under the educational programmes “Preschool Education. Primary Education”, “Preschool Education. Speech Therapy” full-time and part-time study programmes. The readiness of future specialists to use virtual travel to develop the cognitive interest of preschoolers is investigated. For this

purpose, the relevant criteria were developed and their indicators were determined: motivational (need to use virtual travel; desire for new knowledge in this area); cognitive (knowledge of the peculiarities of using virtual travel to develop the cognitive interest of preschool children); activity (ability to use virtual travel in the educational process). The study revealed mostly medium and low levels of readiness of the students who participated in the survey. The authors of the article provide examples of technologies that should be used in working with students to increase their readiness to use virtual travel in teaching preschoolers: Google Earth and Google Maps – for virtual tours of the world, CoSpaces Edu – for creating interactive media content (virtual reality, augmented reality, interactive 3D content), BYOD technology (“bring your own device”) – promotes the integration of mobile learning with other competence-based technologies. The recommendation to reduce the number of applicants with adequate and initial levels of readiness to use virtual travel in the development of cognitive interest of preschool children is to study the relevant elective discipline.

Keywords: cognitive interest, preschool children, virtual travel, student training.

I. INTRODUCTION

An analysis of the scientific literature has revealed the importance of integrating virtual journeys into teacher

Online ISSN 2256-070X

<https://doi.org/10.17770/etr2025vol3.8523>

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training, which helps future teachers develop the skills of using VR technologies to stimulate children's cognitive interest [14].

Research shows that the use of VR excursions not only improves the educational process, but also promotes creative thinking and interest in learning, which is especially relevant for working with preschoolers [12]. In addition, the analysis emphasises the need to choose the right software and tools to create effective virtual journeys, which optimises the learning process and increases its interactivity [13].

The study by Smith et al. demonstrates the effectiveness of using virtual tours (IVR) in teaching social sciences, which is confirmed by a comparative analysis of the results of the experimental and control groups of students. The proposed methodology includes the development of training sessions in a virtual environment, which contributes to increasing students' cognitive interest through interactive immersion in historical events and cultural context. The analysis of the results of the post-test evaluation revealed a significant advantage of students who studied with the help of IVR in understanding and memorising the material, which indicates the effectiveness of this method for the development of cognitive skills.

The study by Rapti, Sapounidis and Tselegkaridis confirms that the use of VR technologies in teaching preschoolers arouses significant interest and enthusiasm among children, which can contribute to the development of their cognitive interest. At the same time, the authors note that VR activities do not always promote cooperation between children, which is an important aspect of preparing students for the effective use of this technology in working with preschoolers. Therefore, the training of future teachers should include strategies for using VR not only to engage children but also to develop their communication and interaction in a group.

The research of Andersen, Makransky and Mayer demonstrates that the use of conceptual models such as BEM allows for a deeper analysis of the interaction between the individual and the digital environment, which is important for the development of effective virtual journeys in preschools. The authors concluded that the use of head-mounted displays stimulates interest in science, which confirms the feasibility of integrating VR technologies into the training of students to work with preschoolers.

Alan Ü. (2023) analyses the impact of virtual field trips (VFTs) on children's early education and interaction with their families, confirming the positive effects on emotional well-being, knowledge acquisition and behavioural development. The author emphasises the importance of good planning and expert involvement, while acknowledging that VFTs cannot fully replace traditional field trips due to the limited possibility of multisensory experience.

Research has shown that the use of virtual travel can increase cognitive interest and interactivity in learning, particularly in the context of climate change and alternatives to traditional field trips [15; 22; 10]. However, it is important to integrate these technologies properly to achieve maximum effect in the educational [9; 18; 4; 8].

The following approaches and technologies for forming the ability of future specialists in preschool and primary education to form the basics of cybersecurity of children of preschool and primary school age are highlighted: problem-based approach, BYOD technology ("bring your own device"), and the method of "flipped learning" [20].

Studies show that the use of virtual tours is an effective tool for developing preschoolers cognitive interest, as well as stimulating their creative thinking through interactive teaching methods. This is emphasised in studies where virtual trips have proven to be useful in increasing children's engagement in the learning process [5; 11]. At the same time, for the successful integration of VR technologies into pedagogical practice, it is important to properly prepare students for the effective use of these tools, in particular, by teaching them how to select and implement appropriate VR resources for working with preschoolers [6; 21].

II. MATERIALS AND METHODS

In the course of the study, we used the following methods: theoretical: the method of analysis and synthesis of scientific data in order to determine the theoretical foundations of the problem of future specialists' readiness to use virtual travel to develop the cognitive interest of preschoolers, synthesis, systematisation and generalisation of theoretical provisions of the problem; empirical: interviews with students about the ability to use virtual travel in the educational process, questionnaires of future specialists in preschool education of Vinnytsia State Pedagogical University.

III. RESULTS AND DISCUSSION

An experimental study was conducted, the respondents of which were 67 2nd year applicants for a bachelor's degree in speciality 012 Preschool Education of Vinnytsia Mykhailo Kotsiubynskyi State Pedagogical University, studying under the educational programmes "Preschool Education. Primary Education", "Preschool Education. Speech Therapy" full-time and part-time students. We studied the readiness of future specialists to use virtual travel to develop the cognitive interest of preschool children. To do this, we developed appropriate criteria and defined their indicators: motivational (need to use virtual travel; desire for new knowledge in the field of); cognitive (knowledge about the features of using virtual travel); activity (ability to use virtual travel in the educational process).

The article also characterises three levels of readiness of future specialists in preschool and primary education to use virtual travel to develop the cognitive interest of preschool children.

High – expressed motivation for continuous self-development and improvement in the use of virtual journeys in the development of children's cognitive interest, readiness to implement advanced pedagogical approaches; in-depth knowledge of digital tools, platforms, resources for virtual journeys; profound skills in applying digital tools, platforms, resources for virtual journeys to develop the cognitive interest of preschool children.

Adequate – growing awareness of the importance of professional and personal development in the field of developing the cognitive interest of preschool children through virtual travel, adequate attitude to the teacher's wishes to take more initiative to expand knowledge in the field of virtual travel; knowledge of digital tools, platforms, resources for virtual travel; ability to apply digital tools, platforms, resources for virtual travel to develop the cognitive interest of preschool children.

Initial – insufficient understanding of the importance of professional and personal development in the field of developing the cognitive interest of preschool children through virtual travel, adequate attitude to the teacher's wishes to take more initiative to expand knowledge in the field of virtual travel; basic knowledge of the theoretical foundations of digital tools, platforms, resources for virtual travel; limited readiness to use knowledge in practice.

The respondents were offered a Google Forms survey that included three sets of questions (13 questions in total), according to the criteria identified. The survey was completed by 67 full-time and part-time students.

The first question of the questionnaire was informative and did not relate to any criterion (Are you familiar with the concept of “virtual travel”?) Respondents were offered the following options: yes, familiar, partially familiar, no, not familiar. Among the applicants who took the survey, 25 are familiar with the concept of “virtual travel”, 28 are partially familiar and 14 are not familiar.

To find out the levels of students' readiness to use virtual excursions with preschoolers according to the motivational criterion, we used three questions covering the relevance of using virtual excursions by preschool teachers in martial law, the importance of self-education of future teachers in the use of virtual excursions to form the cognitive interest of preschoolers, and the names of courses attended by students for self-education. Let us dwell on the analysis of students' answers in more detail.

The first question was: “In your opinion, how relevant is the use of virtual excursions in shaping the

cognitive interest of Ukrainian preschool children under martial law? Please justify your answer (in one sentence)”. When analysing the respondents answers to this question, we paid attention to their awareness of the relevance of using virtual tours in Ukrainian preschool education institutions. If the student named at least two reasons, the level of relevance was high, one was sufficient, and if no reason was named or the answers were unambiguous (for example, “relevant”), the level was initial. It is worth noting that the number of reasons was not the only criterion for dividing students into levels. We also assessed the content and depth of the answer. Here are examples of students' responses that we considered to be of a high level: “the use of virtual tours is extremely relevant, as they facilitate access to quality educational content even in conditions of limited physical mobility and safety”, “unfortunately, real tours are not possible at the moment, but they are part of preschool education, for better development and knowledge of the environment. Therefore, it is possible to use virtual excursions, which are not much inferior to real excursions”, “in the conditions of martial law, the use of virtual excursions is relevant, as they safely and affordably contribute to the formation of cognitive interest in preschool children, providing them with the opportunity to get acquainted with the culture and world even in difficult circumstances”, “the use of virtual trips is relevant, as it is difficult to fully provide preschool children with real trips in the conditions of martial law, especially in the border areas” and “in my opinion, in the context of martial law, the use of virtual tours is extremely relevant, as they provide access to educational materials, stimulate cognitive interest and broaden children's horizons while remaining safe and accessible”, “the cognitive interest of a modern preschooler is successfully realised through the organisation of virtual tours, increases motivation to learn, forms an active personal position in the world around them”, “virtual tours are extremely relevant as they allow children to safely get acquainted with the world around them”. There were 18 such answers.

If the applicant mentioned only one argument for the relevance of virtual travel with preschoolers in wartime and the content of the answers was not as deep and meaningful, we considered it to be of a sufficient level. Here are examples of such answers: “Virtual trips interest children, make them want to see cities and nature in real time”, “virtual trips improve the emotional and mental state of children”, “the use of virtual tours is extremely relevant because they provide safe access to cultural, natural and scientific sites”. There were 23 such students.

If the applicant did not indicate any or the reason was insignificant or formal, the level was initial. Also, students whose answer was formal were classified as initial-level. For example: “I believe that the use of

virtual excursions is a relevant tool for the formation of cognitive interest in preschool children". There were 26 such students.

The second question in the motivational block was the following: "How important is it for a teacher to engage in self-education in the use of virtual travel in shaping the cognitive interest of preschool children? Justify your opinion. Please give at least two reasons for your opinion". When analysing the answers of the students who took part in the survey, we noticed that there were few reasoned answers. Most of the students said that it was necessary for educators to engage in self-education in the field of virtual travel, but they did not give any arguments. Here are some of the answers: "self-development is important in any profession", "self-development is the improvement of knowledge. To be interested in a topic, you need to have this information", "I believe that educators and every person who will work in the kindergarten should engage in self-education – it is important".

Here are some well-reasoned answers, in our opinion: "the relevance of teaching methods: modern technologies are constantly changing, and the educator must have up-to-date knowledge to effectively use virtual trips", "educator self-education affects the quality of learning: awareness of new tools allows creating interesting, interactive and accessible forms of learning for children", "improving educator self-education affects children's motivation: virtual excursions, if properly organised, stimulate interest in learning, forming a desire to explore the world", "educator self-education is a good way to improve the quality of learning". It allows to make preschoolers education more effective, interesting and individualised.

The following answers to this question were somewhat formal and shallow: "improving the quality of the educational process", "increasing children's motivation to learn", "developing children's creative abilities", "forming children's sustainable cognitive interest". We attributed such answers to adequate level of student's motivation in using virtual travel to develop preschoolers cognitive interest. The following answer: "educator's self-education in the field of using virtual tours is extremely important, especially in the context of developing cognitive interest in preschoolers. Here are some reasons why this is important: continuous development of technological skills, expansion of methodological approaches, formation of cognitive interest in children, adaptation to changing conditions, ensuring the safety of children in the digital environment, development of professional competence" was classified as a beginner level. In general, the students' answers to this question were distributed as follows: high – 15, adequate – 18, initial – 34.

In order to find out whether future specialists use the above arguments in their own lives, we proposed the

second question: "What courses have you taken in the last six months on the use of virtual travel in the educational process of preschool education?" If the respondent named at least two courses, it was a high level, if one – adequate, if none – initial. The following results were obtained: 15 students – high level, 37 – adequate, 43 – initial.

Based on the results of three questions, we can determine the levels of readiness of future specialists in preschool and primary education according to the motivational criterion: high – 17, adequate – 41, initial – 37.

The next block of questions was aimed at identifying the levels of readiness of future specialists in preschool and primary education to form the cognitive interest of preschool children according to the cognitive criterion. There were three questions in this block in total. The first question was as follows: "What aspects of children's development, in your opinion, are most influenced by virtual travel?" (*Select all that apply*). *Students' answers were distributed as follows*: cognitive interest – 70, imagination and creativity – 58, broadening of horizons – 60, communication skills – 40. Respondents were also asked to provide their own answers. We did not record any such answers. Since students could choose several options when answering this question, the total result is different from 100%. Based on the results of this question, we received the following levels: high – 21 students, adequate – 24 students, and initial – 22 students.

By offering the students the following question, we planned to obtain a methodological level of knowledge of the algorithm of using virtual journeys to develop the cognitive interest of preschool children. The question was as follows: "Choose the correct option, which indicates the sequence of actions of the educator for the effective conduct of a virtual journey. 1. Formulate the goal and objectives of the virtual journey; 2. Prepare technical means or ask parents if they have the appropriate means at home (in case of remote interaction). 3. Conduct the trip. 4. Provide pedagogical support for the virtual journey. 5. Choose a virtual journey; 6. Analyse the effectiveness of the virtual journey". The following algorithm was correct: 152346. We classified the students who chose the correct algorithm of actions as high level, the students who chose a sufficient algorithm, albeit incorrect, but with 1-2 mistakes, as initial level – such answers, logic and sequence of stages of using virtual journeys are absent or the student did not answer this question at all. The students' levels for this question were distributed as follows: high – 20, adequate – 23, initial – 24.

The next question was aimed at finding out students' knowledge of the technical means of conducting virtual travel. Students could choose several options. The options were as follows: interactive whiteboards – 58,

computers/laptops – 56, tablets 36, VR glasses 52. Students were also offered to write down their own answer. We did not notice any such options. We classified students who chose all the options offered as high, three out of five as sufficient, and two or none as beginner. The students' levels in this question were distributed as follows: high – 31, adequate – 29, and initial – 7. As we can see, the students who took part in the survey are aware of the technical means that can be used to conduct a virtual journey with preschoolers.

Based on the results of three questions, we can determine the levels of readiness of future specialists in preschool and primary education according to the cognitive criterion: high – 17, adequate – 41, initial – 37.

To determine the levels of readiness of future preschool education specialists to use virtual travel according to the activity criterion, we offered students two questions. Let us analyse the students' answers.

First question. Watch the video. Write 3-5 questions that you would ask children after they have watched this virtual tour of Ukraine to develop their curiosity(<https://www.youtube.com/watch?v=o1kRNXRI NTY>).

If the questions that the educator asks the children after watching the virtual journey are reproductive in nature, such as what did you see in the video? Would you like to go there? Have you ever been to such places? – initial level. If the questions were of a problematic nature, for example: What new animals or plants did you see? What interesting places do you remember from our trip? Why do you think these places are important for our country? What impressed you most about this trip? Would you like to visit one of these places in real life? Why? What new facts did you learn about Ukraine? What was most interesting? Why? If you answered yes, this is a sufficient level. If the answer contained both reproductive and problematic questions, it is sufficient. The results are as follows: high – 14, adequate – 27, initial – 26.

The second question of the activity criterion: Watch the video. What changes would you make to the video to make it more conducive to the development of preschoolers cognitive interest? (<https://www.youtube.com/watch?v=yeMdjacQ2M>).

The video offered to students contains a trip around the world. Let's analyse the students answers. If the student's answer was constructive and meaningful, this is a high level. For example: “For a more favourable development of preschoolers, I would replace the background of the video with brighter pictures and add animation. To introduce the globe, I would put a picture of a rotating globe. To study European countries, I would first introduce children to Europe, tell them about it and then about its countries. I would insert a map with clearly marked borders, more interesting information about the countries, pictures of animals that live there, people, their

clothes, traditions, etc.”, “In my opinion, this is more of an informative story than a virtual journey. I think it would be necessary to plot the route on a world map so that children understand where a particular country is located. I would also add video fragments about each country so that children could see the peculiarities of each country”, “Add more interactive moments (questions, tasks for children). Use more colourful visual effects. Add game or animation elements. I would add video fragments, more interesting material and improve public speaking skills”.

If the answer to this question was less thorough (for example: “Add interactive elements, such as questions or tasks that children can do while watching”, “use colourful graphics and animation to enhance the visual experience”, “include an interesting narration by a character who accompanies children on the journey”, “show more real-life examples that children can recognise or relate to”, “focus on emotional moments that evoke surprise or admiration, such as unique natural phenomena or unusual buildings”). If there was no answer to this question or it was not independent, the level was initial. The results are as follows: high – 16, adequate – 29, initial – 22.

Based on the results of two questions, we can determine the levels of readiness of future specialists in preschool and primary education according to the activity criterion: high – 15, adequate – 28, initial – 24. The generalised data can be seen in Table 1.

TABLE 1.LEVELS

	high	sufficient	low
motivational	16	26	25
cognitive	24	25	18
operating	15	20	24

We also conducted interviews with students to provide more detailed answers to certain questions in the questionnaire. The results of the interview confirmed the results of the questionnaire. During the conversation, students shared their thoughts that they were interested in the use of virtual travel in the educational process of preschool education and would like to gain additional knowledge on this issue, for example, in an elective course. If there is no such opportunity, they plan to engage in self-education in the use of virtual journeys to form the cognitive interest of preschool children.

In conclusion, here are examples of resources and technologies that should be used in working with students to increase their readiness to use virtual travel in developing preschoolers cognitive interest: Google Earth and Google Maps – for virtual tours of the world, CoSpaces Edu – for creating interactive media content (virtual reality, augmented reality, interactive 3D content), BYOD technology (“bring your own device”) –

promotes the integration of mobile learning with other competence-based technologies. In our opinion, it will be extremely interesting for preschoolers to make a virtual trip to other planets, as such a trip is impossible in real time.

In particular, you can take a trip to Mars, recorded by the Curiosity rover, at the following link: <https://accessmars.withgoogle.com/#>. It will also be interesting for preschoolers to visit Ukrainian open-air museums: <https://museums.authenticukraine.com.ua/ua/>, using the Google Arts & Culture digital platform, you can travel to 17 museums around the world (<https://artsandculture.google.com/>), the Georgia Aquarium, you can watch penguins, piranhas or exotic jellyfish via a web camera by visiting the largest oceanarium in Atlanta, USA (<https://www.georgiaaquarium.org/webcam/ocean-voyager/>), you can see picturesque panoramas created thanks to tens of thousands of photos from around the world on the 360cities.net Panorama platform (<https://www.360cities.net/>).

IV. ACKNOWLEDGMENTS

We express our gratitude to the 2nd year students of the higher education degree “Bachelor” of speciality 012 Preschool Education of Vinnytsia Mykhailo Kotsiubynskyi State Pedagogical University, who are studying under the educational programmes “Preschool Education. Primary Education”, “Preschool Education. Speech Therapy” full-time and part-time study programmes.

V. CONCLUSIONS

Preparing students to use virtual travel in their work with preschoolers is an important and promising area of teacher education. Mastering this tool contributes to the development of digital competence of future teachers, helps to create interesting and interactive lessons that increase the level of cognitive interest of children.

The main characteristics of a virtual journey are the organisation of remote communication between participants in the educational process, time management for learning, mobility and accessibility, and stimulation of creativity in educators and children.

The results of the study showed that the effective use of virtual journeys in the educational process of preschool education institutions requires students to master modern digital technologies and online resources; methodological skills for integrating virtual journeys into various educational areas; understanding the age characteristics of preschoolers to create meaningful and accessible journeys.

The following technologies should be used in working with students to increase their readiness to use virtual travel in teaching preschoolers: Google Earth and Google Maps, CoSpaces Edu, BYOD technology.

The research conducted does not cover all aspects of the problem under consideration. Further research is needed to study the possibilities of combining virtual travel with other interactive teaching methods and to develop methodological recommendations for teachers on the optimal use of this tool in the educational process.

In the article, the authors made an attempt to actualize the problem of the readiness of future preschool and primary education specialists to form the foundations of children's cyber security. In connection with the increase of threats on the Internet and the use of gadgets by children from an early age, it is necessary to develop children's ability to use the Internet safely, to be conscious citizens of the digital world. For this, it is necessary to train future specialists in preschool and primary education.

The following approaches and technologies for the formation of future specialists of preschool and primary education in the ability to form the basics of cyber security of children of preschool and primary school age are singled out: problem-based approach, BYOD technology (“bring your own device”), the method of “inverted learning”.

The conducted research does not cover all aspects of the problem under consideration. The question of forming the motivation of preschool and primary education specialists for independent continuous professional development in the field of cyber security requires further research.

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Training of Future Specialists for the Formation of the Foundations of Media Literacy of Children of Preschool and Primary School Age

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Abstract- In connection with the digitization of the educational process, the need for the development of critical thinking of children of senior preschool and junior school age, the development of the ability to use information in any form, to communicate, and to understand the consequences of interaction in the digital world is increasing. The article proves that media literacy of a modern people is the basis of their security in the information society. It is found out that the training of future specialists in preschool and primary education should include the formation and development of methodological competence of students for the formation of media literacy and information culture of children of preschool and junior school age, as well as the creation of an educational and informational environment in a preschool education institution. Emphasis is placed on solving the following tasks: to form the ability to implement a systematic approach to the introduction of media education in preschool and primary school; to form the ability to protect children from an aggressive media environment; to form the ability to use media technologies in order to organize media creativity of children of senior preschool and junior school age; to form a certain level of information culture of future specialists; to instill future educators' creative approach to the formation of the foundations of children's information culture; to form the need for future preschool and primary education specialists in self-education in accordance with the requirements of the information society. In the course of this study, we used the

following methods: theoretical: analysis of scientific sources to determine the state of research on the problem of forming media literacy of preschool children and training future preschool education specialists to form media literacy of children. Synthesis, systematization and generalization of theoretical provisions of the problem were used; empirical: pedagogical observation of children's activities in 18 preschool education institutions, conversations with preschool education teachers regarding the implementation of activities to form the foundations of media literacy of preschool children, conversations with students about the relevance of the problem of forming media literacy of preschool children, questionnaires of future preschool education specialists of the Mykhailo Kotsiubynskyi Vinnytsia State Pedagogical University. The experimental study was conducted, the respondents of which were bachelor's degree holders of the specialty 012 Preschool Education and 013 Primary Education of Vinnytsia Mykhailo Kotsiubynskyi State Pedagogical University. The following approaches and technologies for the formation of future specialists of preschool and primary education in the ability to form the foundations of media literacy and information culture of children of preschool and senior school age have been singled out: a problem-based approach, BYOD - technology ("bring your own device"), the method of "inverted learning".

Online ISSN 2256-070X

<https://doi.org/10.17770/etr2025vol3.8532>

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Key words- *Educational process of primary school, junior schoolchildren, educational process of preschool education institution, media literacy, information culture, innovative BYOD technology.*

I. INTRODUCTION

Children are exposed to media information at an early age. In fact, they are in a media environment from birth. Information comes from everywhere - from the TV, parents' phones, computers, tablets, that is, from various devices used by parents. And although the child does not yet know how to speak, his consciousness is not developed, the information affects the subconscious and is "recorded" there, being the basis for a worldview. Later, imitating his parents, children from an early age begin to use a tablet, touch phone, laptop. Parents, not realizing the consequences, give their children a tablet and a phone so that they do not interfere. Thanks to this, children can hear and see information that is unacceptable to them. Therefore, it is necessary to start introducing children to possible threats on the Internet from an early age, to form the skills of safe use of gadgets, and to form a critical attitude towards information. Another problem is the lack of understanding by many parents of the importance of forming the foundations of media literacy in their children. In today's world, it is important to teach children from an early age to be conscious citizens of the digital world. Another problem is the lack of knowledge of parents about the basics of their own media literacy.

The formation of the basics of media literacy of preschool children is not new in domestic and foreign scientific research. In particular, the following were studied: the impact of media (television, Internet) on the development of infants, toddlers, and preschoolers, and how parents perceive and use media in combination with their style of conversation with children, shape not only language skills throughout life, but also other qualities [10; 3], the convergence of imagination, social-emotional learning, and media literacy [10], the importance of television and media literacy for young children [4], awareness and use of social networks by preschool children [3], digital media patterns among parents and preschoolers in Thailand [12], the impact of television on the development of young children [1], digital media and self-regulation skills of preschool children [6], Preparation future specialists in preschool and primary education to form the foundations of children's cyber safety [13].

Due to the digitalization of the educational process [5; 7], the need to develop critical thinking in older preschool children is increasing [8].

However, we have identified a contradiction between the speed of development of media technologies and the training of specialists in preschool education. The authors

of the publication present their own view on solving this problem in this article.

II. MATERIALS AND METHODS

In the course of this study, we used the following methods: theoretical: analysis of scientific sources to determine the state of research on the problem of forming media literacy of preschool children and training future preschool education specialists to form media literacy of children. Synthesis, systematization and generalization of theoretical provisions of the problem were used; empirical: pedagogical observation of children's activities in 18 preschool education institutions, conversations with preschool education teachers regarding the implementation of activities to form the foundations of media literacy of preschool children, conversations with students about the relevance of the problem of forming media literacy of preschool children, questionnaires of future preschool education specialists of the Mykhailo Kotsiubynskyi Vinnytsia State Pedagogical University.

The study was conducted from April to December 2024. The survey was attended by 53 full-time 2nd-year Bachelor's degree applicants from the Faculty of Preschool and Primary Education named after Valentina Voloshyna, specialty 012 Preschool Education, Vinnytsia Mykhailo Kotsiubynskyi State Pedagogical University (Vinnytsia, Ukraine).

The survey window was open for 2 weeks: from September 2 to September 16, 2024. Participation in the online survey was voluntary.

III. RESULTS AND DISCUSSION

An experimental study was conducted, the respondents of which were 53 2nd year students of the higher education degree "Bachelor" in the specialty 012 Preschool Education of the Mykhailo Kotsiubynskyi Vinnytsia State Pedagogical University, who study in the educational programs "Preschool Education. Primary Education", "Preschool Education. Speech Therapy" of the full-time and part-time forms of study. We studied the level of media literacy of future specialists. Based on the existing level of media literacy, we can plan further pedagogical work.

Respondents were offered a survey in the classtime resource, which included eight questions. 53 full-time students took the survey. A student who scored 18-20 points - a high level of media literacy, 15-17 - an average level, 12-14 - an initial level.

Let's analyze the students' answers.

In the first question, students were asked to distinguish a fact from a judgment. Only 15 answers were incorrect. Therefore, we can conclude that almost a third of the students who took the survey do not know how to distinguish fact from judgment. This, in our opinion, is a fairly large percentage.

The second question did not differ from the first in essence. But, unlike the first, it was specific: "The Ukrainian language was recognized as the most beautiful in the world after French and Persian at a language competition in Paris in 1934." This statement is a judgment, since there are no clear, generally accepted norms that would regulate the language as the most beautiful. The concept of "the most beautiful" is subjective, and therefore cannot be a fact. Only 12 respondents who took the

survey gave the correct answer to this question. Comparing the students' answers to the first question (there were 28 correct answers to the first question, and only 12 to the second), we can state that students have theoretical knowledge about the difference between a fact and a judgment, but a significant number of respondents do not have the skills to distinguish a fact from a judgment in practice.

The next question was also aimed at identifying students' ability to distinguish facts from judgments in practice. The question sounded like this: "The geographical center of Europe is located in the town of Rakhiv, surrounded by the picturesque Carpathians. Is this true?" There were 18 correct answers, which is not much different from the 12 from the previous question. Based on this, we can conclude that some judgments are so firmly embedded in our lexicon that we perceive them as facts.

The purpose of the next, fourth question was to find out whether students know what "clickbait" is. The question sounded like this: "Clickbait is: 1) usually perceived inseparably from the person who reports it and does not exist without its author; 2) the tendency to formulate sensational headlines, supported by images, to attract the attention of readers in order to force them to click on the link is the correct answer; 3) the use of information for fraudulent or selfish purposes by distorting, providing incomplete information, biased interpretation.

Of the proposed options, the second answer was correct. Surprisingly, only 11 students answered this question incorrectly, while 42 answered it correctly. Such results indicate that the students who took the survey are familiar with the concept of clickbait and understand its essence.

The next question was intended to test students' knowledge of ways to counter propaganda on a personal level. The answer had to indicate the correct algorithm of actions for this. The correct answer would be: 1- Step away from your emotions, 2- Separate facts from judgments and assessments; 3- Check the given facts; 4- Analyze the available methods of influence; 5- Ask yourself the question: who is the message aimed at, who is the target audience? What does it call or encourage? Who can benefit from it? Why is the message being spread right now?

As it turned out, this question was difficult for students, since only 10 out of 53 answered correctly.

The next, sixth question was: "What do algorithms collect about you (select all correct options)." The following options were offered to students: "your 'likes' and 'dislikes', 'who you communicate with', 'your reaction to advertising', 'what you are looking for on the Internet', 'personal data (status, age, city of residence, study)', 'all your comments and discussions'. All of these options were correct. Only 14 students from those who took the survey chose all the options.

In the next, seventh question, we aimed to find out whether students know what an information bubble is and how harmful it is. We counted the answer as correct if at least 2 arguments were named. There were only 13 incorrect answers to this question. Based on this, we can conclude that 40 students know how harmful an information bubble is. Although, there is another explanation. Since the students took the survey online, accordingly, they had the opportunity to use the Internet search. Let us note the correct answers. "You are alone with one piece of information without the opportunity to learn something else -

it is easier to manipulate you. You yourself begin to believe in the information that is heard every day, the same thing, you become dependent on it, you are convinced that it is all true", "contributes to disinformation, limits the worldview, limits critical thinking", "a person receives one-sided information, which interferes with critical thinking. The illusion is created that everyone thinks the same way, which can cause misunderstanding or aggression towards other views.

In the last, eighth question, we offered students to choose markers of fakes. Among the proposed options were the following: 1) dubious source of distribution; 2) grammatical errors, signs of translation from another language; 3) lack of specificity in the "fact"; 4) increased emotionality of the message; 5) a request to follow the link; 6) distortion / fabrication of positions, surnames, etc.; 7) inconsistency of dates, numbers, statistical data; 8) appeals, requests, conspiracy theories; 9) lack of emotion in the message. Among the proposed options, 5 and 9 are incorrect. Let's analyze the results. Unfortunately, there were no students who did not make any mistakes. One answer out of 7 was given by 7 students, two correct answers out of 7 were given by 8 students, three out of seven were given by 10 students, four out of seven were given by 10 students, five out of seven were given by 7 students, and six out of seven were given by 11 students. There were also students who chose the wrong options. If a student chose the wrong option as the correct one, the classtime resource did not count this as an incorrect answer.

Here are the final results we received: high level – 11 students, medium – 28, primary – 14. The results indicate that it is necessary to provide students – future specialists in preschool education with information about ways to develop media literacy of adults and preschool children. We also conducted a conversation with students at the end of the questionnaire. We asked the following questions to future specialists in preschool education: how relevant is the level of media literacy of a person for their effective interaction in society? How important is it to form the media literacy of preschool children? What methods of forming media literacy of preschool children do you know? Is it necessary to involve parents? What forms of interaction with parents would you choose (in addition to traditional parent meetings) in the issue of forming the media literacy of their children.

During the conversation, the students reported that media literacy is a vital quality of a modern person, since in the modern world there is a lot of multidirectional information, various fakes and propaganda. Especially under the conditions of martial law in which Ukraine is located. Also, since media technologies are developing rapidly today, and modern children are practically in a media environment from birth, the formation of their media literacy is extremely relevant. Of the methods for forming media literacy in preschool children, the students named only games and explanations. They also said that the formation of media literacy in preschool children would be more effective if they cooperate with parents. However, they could not name other forms of cooperation, except for parent meetings.

We also conducted observation of the educational process in 18 preschool educational institutions in Vinnytsia. The results of the observation are as follows: in 10 kindergartens, educators do not conduct media educational activities. In personal conversations with educators, we found out the reason.

Educators consider the sphere of forming media literacy in children to be a matter of home education. In eight other kindergartens, educators conduct special conversations, games, quests, and watching cartoons with the aim of forming media literacy in children. And also these educators conduct various activities aimed at motivating parents to learn media literacy knowledge with their children.

Based on a survey of 2nd year students of the specialty 012 Preschool Education, we offer students an elective academic discipline "Formation of the basics of media literacy of preschool children". Since modern learning has become mobile, and the teacher is no longer the only source of information, we offer non-traditional forms and methods of developing media literacy of future preschool education specialists. Such forms include visiting the media literacy labyrinth.

The Media Literacy Labyrinth is a mobile structure the height of a one-story building, consisting of 12 rooms, in each of which visitors receive useful knowledge and skills necessary to increase their media literacy in an interactive format. The Media Literacy Labyrinth "NOT BELIEVE - CHECK" was created as part of the "Dream and Act" program, which is implemented with the financial support of the United States Agency for International Development (USAID) and implemented by IREX in partnership with Building Ukraine Together (BUU), Making Cents International (MCI), and the International Republican Institute (IRI).

This labyrinth is the only one in Ukraine. In this labyrinth, visitors are offered interactive tasks and games that will help them "catch" fakes, expose manipulations, distinguish between fact and opinion. There is also an opportunity to test their knowledge and critical thinking skills and make a person resistant to disinformation. The website (<https://mriemotadiemorazom.org/nevirrrpervirr>) contains brief information about which rooms are in the labyrinth. The labyrinth began its journey across the country in 2021 and has already been to Kyiv, Vinnytsia, Slavutych, Lviv, Rivne, Ivano-Frankivsk, Zhytomyr, Chekasy.

As part of informal education, we offer students an online course on the basics of media literacy on the EdEra platform. The online course is active by appointment: <https://study.edera.com/uk/courses/course/2118>.

During classroom lessons on the formation of media literacy of future preschool education specialists, we offer to use a problem-based approach. Problem-based presentation of knowledge (rather than a traditional monologue) during lectures and partially search and search-based during practical classes. To activate students in the formation of their media literacy, we ask whether they have encountered false information in the media? How to distinguish the true from the false? Do they know how to make fakes? Have they met scammers on social networks? Or do they know such stories of their relatives and friends? We ask them to share and supplement. A problematic question can be asked at the beginning of a new topic and thus motivate students to study it. By asking a problematic question at the end of the lesson, we motivate them to study a new topic in the next lesson. Students like such methods, because they feel like equal participants in the educational process.

We also suggest using BYOD technology ("bring your own device"). At Mykhailo Kotsiubynskyi Vinnytsia State Pedagogical University, since 2020, training has been taking

place in a blended format. This decision was made in connection with Covid-19 and then martial law in Ukraine. Both during full-time and distance learning, during lectures and practical classes, we offer students to find certain information using their own devices. This makes learning dynamic, interesting, and motivates students to acquire new knowledge in the field of media education.

IV. ACKNOWLEDGMENTS

We express our gratitude to the teachers and students of the Department of Pre-school Education of the Mykhailo Kotsiubynskyi Vinnytsia State Pedagogical University, to the teachers of Pre-school Education Institution No. 30 and 27 in the city of Vinnytsia

V. CONCLUSIONS

In the article, the authors attempted to actualize the problem of training future preschool education specialists to form the foundations of children's media literacy. Due to the increasing speed of development of media technologies, negative content in the media environment, fraudulent actions, it is necessary to form children's media literacy from an early age, to be conscious citizens of the digital world. For this, it is necessary to train future specialists in preschool education.

The following approaches and technologies for forming the skills of future preschool education specialists to form the foundations of media literacy of preschool children are identified: a problem-based approach, BYOD technology ("bring your own device"), non-standard forms, in particular, visiting a media literacy maze.

The study does not cover all aspects of the problem under consideration. Further research is needed to form the motivation of preschool education specialists for independent continuous professional development in the field of media literacy and to involve parents in this.

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Advantages and Disadvantages of Distance Learning in Ukrainian Higher Education Institutions Under Martial Law

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Abstract- Since 2020, due to objective reasons (first the Covid-19 pandemic, then the war), many Ukrainian educational institutions have not been able to organize a systematic educational process in a face-to-face format. Educational institutions have to combine different forms of education in order to establish effective interaction and ensure high-quality acquisition of knowledge. In the conditions of quarantine restrictions, and later martial law in Ukraine, the distance form turned out to be the most optimal and safest option for organizing education. The article examines the advantages and disadvantages of distance learning based on a survey of applicants for a bachelor's degree who are studying in the specialty 012 Preschool Education at Vinnytsia State Pedagogical University. A total of 53 applicants who have been studying using distance learning technologies for 4 years were surveyed. The following questions were investigated: what difficulties did students encounter at the beginning of distance learning, how did they overcome them; dynamics of attitude towards distance learning (over four years of study); analyzed the difficulties (and psychological ones, in particular) that applicants faced, and how they solved them. The advantages of distance learning were the opportunity to spend more time with family, save time traveling to the university, mobility of learning (the ability to study anywhere at any time). Disadvantages: lack of "live" communication and technical problems that arose during distance learning. In the course of this study, we used the

following methods: theoretical: analysis of scientific sources to determine the state of research on the problem of organizing distance learning in Ukrainian and foreign higher education institutions. The synthesis, systematization and generalization of theoretical provisions of the problem were used; empirical: pedagogical observation of the organization of distance learning at the Vinnytsia State Pedagogical University named after Mykhailo Kotsiubynskyi of students of the specialty 012 Preschool Education, conversations with teachers of the Department of Preschool Education of this university, conversations with 4th-year students of the specialty 012 Preschool Education of full-time and correspondence studies. The survey lasted 8 days: from September 9 to 16, 2024. Participation in the online survey was voluntary. To increase the effectiveness of distance learning, it is recommended to increase the digital competence of teachers of higher education institutions in the use of various digital tools and a humanistic orientation to create a more comfortable environment. The features of using BYOD technology ("bring your own device") in conditions of distance learning are noted.

Keywords- distance learning, higher education, bachelor's degree applicants, master's degree applicants, problem-based approach, innovative BYOD technology.

Online ISSN 2256-070X

<https://doi.org/10.17770/etr2025vol3.8548>

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I. INTRODUCTION

In Ukraine, distance learning has become widespread, starting in 2020, when there was a sudden outbreak of the Covid-19 pandemic. Subsequently, martial law in Ukraine forced many educational institutions, and higher education institutions in particular, to remain on distance learning or switch to a blended format. Currently, the situation in Ukraine has not changed and this is a prerequisite for studying the features of organizing distance learning in higher education.

Discussions of the problems of organizing distance learning with colleagues at scientific seminars and conferences of various levels allow us to assert that the vast majority of teachers of higher education institutions in Ukraine were not technically and methodologically ready to implement such training. The findings of the study [8] indicate that as of 1999, there was no original research devoted to explaining or predicting phenomena related to distance learning, and second, although most studies show that distance learning courses are superior to classroom-based learning, the overall quality of the research is questionable, making the results inconclusive. The authors identified key research shortcomings including: (1) most studies do not control for extraneous variables and therefore cannot show cause and effect; (2) most studies do not use randomly selected subjects; (3) the validity and reliability of the instruments used to measure student outcomes and attitudes are questionable; and (4) many studies do not adequately control for the feelings and attitudes of students and instructors.

In subsequent years, scholars have sought ways to improve the effectiveness of online courses in higher education [3].

The problem of transitioning to distance learning has been faced by teachers in higher education institutions in various countries: India [1], Morocco [4], Albania, Italy, Morocco, Algeria [5], Turkey [7].

After the forced distance learning, scholars became interested in studying the experience of conducting such training to determine ways to increase its effectiveness. Recommendations were made at the teaching and technical levels, such as the need for technical support and training in the use of these tools, to improve and promote distance education in Morocco [4].

It is worth noting the researched technologies for increasing the efficiency of distance learning in higher education institutions - this is the use of artificial intelligence [6], understanding technological capabilities and theories of learning, especially constructive theory and theory of independent learning, communicative theory and theory of interaction in distance learning [7], developing a model of distance learning in a higher education institution [2] and equipping students with skills for safe use of the Internet [9].

Thus, a review of scientific sources indicates the prospects of distance learning, if it is based on new communications and will be an important factor in future strategies of higher education, on the one hand, and on the other - the need to systematically study the features of organizing such learning to increase its efficiency.

II. MATERIALS AND METHODS

In the course of this study, we used the following methods: theoretical: analysis of scientific sources to determine the state of research on the problem of organizing distance learning in Ukrainian and foreign higher education institutions. The synthesis, systematization and generalization of theoretical provisions of the problem were used; empirical: pedagogical observation of the organization of distance learning at the Vinnytsia State Pedagogical University named after Mykhailo Kotsiubynskyi of students of the specialty 012 Preschool Education, conversations with teachers of the Department of Preschool Education of this university, conversations with 4th-year students of the specialty 012 Preschool Education of full-time and correspondence studies.

The study was conducted from February to December 2024. 124 4th-year students of the full-time and correspondence studies of the Faculty of Preschool and Primary Education named after Valentyna Voloshyna of the specialty 012 "Preschool Education" of the Vinnytsia State Pedagogical University named after Mykhailo Kotsiubynskyi (Vinnytsia, Ukraine) participated in the questionnaire.

The survey lasted 8 days: from September 9 to 16, 2024. Participation in the online survey was voluntary.

III. RESULTS AND DISCUSSION

An experimental study was conducted, the respondents of which were 124 4th-year applicants for a bachelor's degree in specialty 012 Preschool Education of the Mykhailo Kotsiubynskyi Vinnytsia State Pedagogical University, who study in the educational programs "Preschool Education. Primary Education", "Preschool Education. Speech Therapy" of full-time and part-time study.

We studied students' attitudes towards distance learning. Based on the opinions of students, we can more effectively make changes to the organization of distance learning.

The survey was conducted by students who had been studying remotely for 3.5 years.

The first question was: "What was your attitude to the news that you will be studying in a distance format? Neutral - 57, positive - 42, negative - 25,

As part of our study, it was interesting to find out whether students encountered difficulties at the beginning of distance learning in 2020. It is worth noting that in March 2020, the distance learning format at Vinnytsia State Pedagogical University was chosen due to the rapid spread of the Covid-19 pandemic. The question to students was as follows: "What difficulties did you encounter at the beginning of distance learning?" We offered students to choose from the following options: technical support 64, insufficient level of digital skills 40, psychological discomfort from unusual learning conditions - 56, there were no difficulties - 8. Since in this question students could choose several options, the sum does not equal 100%. As we can see, the most difficulties for students were related to technical support. Eight students did not experience any difficulties. It was also interesting to find out whether students experienced difficulties during distance learning. Therefore, the next question was as follows: "Did you experience difficulties during distance learning?" Let's

consider the students' answers. The answer "yes, I had difficulties" was chosen by 41 students, "no" - 77 students, I had difficulties at the beginning of the distance format, and then I adapted - 4.

With the next question, we wanted to find out what difficulties the students had. Let's analyze the students' answers. Some students had difficulties related to health. They solved them with the help of treatment and sports. In our opinion, such a difficulty is not related to the distance learning format. Moreover, during distance learning it is even easier to solve health problems, since the teaching staff of the Department of Preschool Education of Mykhailo Kotsiubynskyi Vinnytsia State Pedagogical University always helps students in such issues. One of the options is to record videos during lectures, practical, laboratory classes and place them in the virtual environment of Google Classroom. In this case, the student can familiarize himself with the theoretical material that was considered at the lecture. After watching the video of the practical lesson, the student has an idea of the form the lesson took, how the teacher evaluates the answers, what to emphasize in his answer. And, finally, the student can attach the completed assignment to Google Classroom without penalties.

Some students overcame minor technical difficulties on their own, while others turned to teachers.

Some students had difficulties because they had to go to work and it was difficult to combine study with work. In this, in our opinion, the distance learning format can be the solution to this problem. After all, as we have already noted above, a student can watch videos in the virtual environment of Google Classroom at a convenient time. And also add a completed task.

However, there was a difficulty that became a challenge for both students and teachers. We are talking about power outages. Due to martial law in Ukraine, there were power outages that continue today. This was noted by almost all students who were surveyed. The exceptions were students who were abroad. As evidenced by the analysis of the deadlines for submitting work by students to the virtual environment of Google Classroom, we noticed that students who studied responsibly systematically submitted their work. And students who were not conscientious about their studies during offline learning turned in their assignments in Google Classroom on time. Personal conversations with students confirmed the conclusion that problems with power outages are not the key to students' failure. Students noted that when there were problems with power outages and unstable Internet, they turned to the teacher.

The next question was: "Has your attitude towards the features of distance learning changed now, compared to the beginning?" yes - 88, no - 36.

The next question "What are the changes in attitude towards distance learning related to?" We offered students the following options: "during the study process, I acquired digital skills necessary for this type of study" - 78, "I learned to combine study with work, family, etc." - 14, I feel a lack of "live" communication - 32. In response to this question, students were able to choose several options, so the sum will be different from 100%. In response to the next question, we asked students to indicate the advantages of distance learning

that occurred in their experience (you can choose several options). Students made the following choices: the opportunity to spend more time with their family - 96, saving time on traveling to the university - 104; the opportunity to simultaneously obtain another specialty - 8; the opportunity to work - 97; while abroad, I have the opportunity to study - 7; mobility of study (the opportunity to study anywhere at any time) - 112; opportunity to travel and study - 24. In answering this question, students were able to choose several options, so the sum will be different from 100%. As we can see, the following advantages are prioritized: mobility of study, spending more time with family, saving time on traveling to university. In this question, students were also asked to name their option. However, no such answers were recorded.

In the next question, we asked the students who took the survey to indicate the disadvantages of distance learning. The answers were as follows: lack of "live" communication - 72, difficulty in perceiving and mastering the material - 8; difficulty in performing practical and laboratory work - 6; problems in passing the test/exam online - 0; technical problems that may arise in the process of distance learning - 112. Thus, we can see that the main disadvantages of distance learning are seen by students as technical problems and lack of "live" communication.

As part of our study, we were interested in who students turned to for help when they had (or could have had) psychological difficulties in the process of distance learning. We offered the following options: to classmates - 48; to teachers (teacher) - 32, to a psychologist - 0; to relatives, friends - 56; I don't turn to anyone, I'm used to solving problems on my own - 42. As we can see, the students who took the survey prioritized their family and friends. And it was their family that they would turn to or did turn to for help in solving problems that occurred during distance learning. Another area of our research was the study of what digital tools teachers use in distance learning. What web resources did teachers use during distance learning? Google Classroom - 112; Google Meet - 120; Google it - 0; Google Drive - 64; All Google Apps - 17; Zoom - 113; LearningApps - 104; Miro - 32; Padlet - 71; Classdojo - 0; Classtime - 112. Students were also offered their own option to answer this question. However, there were no such answers. In answering this question, students were able to choose several options, so the sum will differ from 100%. As we can see, teachers use applications such as Google Meet, Google Classroom, Zoom the most and do not use Classdojo and Google it at all.

To understand what functions resources for distance learning should have, we asked students the following question: "Indicate the properties of digital resources, platforms that are necessary for distance learning?" Here are the students' answers: "Adaptability, convenience, accessibility, interactivity, diversity", "resources related to creating presentations, interactive games, educational and methodological resources with tests, interesting tasks", "it is important for me that resources provide the possibility of effective interaction, cooperation and exchange of information between participants in the educational process, as well as contain content that is interesting for children", "interactivity, flexibility and the ability to accept many participants", "participation and interactivity".

Finally, we asked students questions about the recommendations they would give to teachers of higher education institutions in organizing distance learning. Having analyzed the students' answers, we can combine them into two groups. The first group is wishes in the educational and methodological sphere. Among the recommendations, we note those that were encountered most often: "I would advise you to choose a platform for meetings well, so that it is convenient and understandable for everyone", "When explaining the material, create an additional presentation, or show photos, so that it is easier to remember", "conduct more interactive and practical exercises", "look for more interesting sites to make the lesson more interesting", "create a more flexible schedule so that you can spend less time at the computer", "use more modern technologies". The second group is psychological wishes. They included: "Pay more attention to the condition of those who are studying and your own; unite and contribute to building a friendly team; take into account the moral state of students; support when necessary, become a reliable shoulder for students; in educational work, take into account the current situation in the country", "be able to correctly combine loyalty and rigor, so as not to push students away, but to show authority". There were students who noted that they liked how distance learning was organized at the Mykhailo Kotsiubynskyi Vinnytsia State Pedagogical University

Thus, the empirical study conducted allowed us to identify the following features: students who took the questionnaire developed by us were only worried at the beginning of distance learning, and then solved the problems; during distance learning, they noticed the advantages of such learning (the opportunity to be at home with their family, not to spend money on traveling to the university and paying for housing, working, raising children), they consider the use of digital tools by teachers to be insufficient, they propose to diversify digital tools that would ensure interactivity, interaction between students and clarity.

V. CONCLUSIONS

In the article, the authors made an attempt to investigate the advantages and disadvantages of distance learning. From the empirical research methods, a questionnaire was used for 4th-year bachelor's degree applicants studying in the specialty 012 Preschool Education at the Mykhailo Kotsiubynskyi Vinnytsia State Pedagogical University. The uniqueness of the study lies in the fact that the students who took the questionnaire have been studying in a distance format for 3.5 years. A total of 124 full-time and part-time students participated in the questionnaire. The study revealed more advantages of distance learning than disadvantages. The students considered the advantages to be the opportunity to be at home with their family, not to spend money on traveling to the university and paying for housing, to work, and to raise children. However, the quality of distance learning can be fully assessed during the final certification, where students will be able to demonstrate their knowledge over 4 years of study.

To increase students' interest in acquiring professional knowledge, according to the authors of this article, the use of a problem-based approach in teaching, the latest digital tools for interactivity, interaction between students and feedback from the teacher to students, and the use of BYOD technology will help.

The conducted research does not exhaust all aspects of the problem under study. Further research is required to study the impact on students' motivation to acquire knowledge and form competencies in a distance format.

Further scientific developments are required to study the formation of students' motivation for learning under the conditions of distance learning.

IV. ACKNOWLEDGMENTS

We express our gratitude to the teachers, students of the Department of Preschool Education and the administration of the Mykhailo Kotsiubynskyi Vinnytsia State Pedagogical University.

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Digital Applications in Physical Education: Experience, Benefits, and Implementation Challenges

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Abstract— The article presents the attitudes of physical education teachers toward the use of digital applications, highlighting their advantages and challenges. The aim is to examine teachers' perspectives on the implementation of digital applications in physical education and identify their benefits and difficulties. The study employed literature analysis, surveys, and statistical processing of research results. It was found that 62,9% of teachers incorporate digital applications into their pedagogical practice, while 42,9% started using them during the strict lockdown period. Additionally, 37,1% primarily apply them in distance learning and occasionally in face-to-face lessons. Among various digital tools, teachers prefer interactive learning platforms (67,1%), fitness trackers (34,3%), and applications for monitoring pupils' health (30,0%).

Regarding the impact, 31,4% of teachers recognize the positive influence of digital applications on pupils' motivation, 52,9% believe they facilitate individualized learning, 41,4% consider them effective for health-related tasks, and 48,6% note their role in developing pupils' physical qualities. However, the effectiveness of digital applications in achieving educational (31,5%) and educational-social (25,7%) objectives in physical education remains low.

The study identifies key advantages, such as access to diverse educational materials (47,1%), individualized learning (32,9%), increased pupil motivation (20,0%), improved progress monitoring (17,1%), and enhanced communication with pupils and parents (15,7%). Challenges include difficulties in integrating applications into the learning process (71,4%), lack of time for preparation and implementation (62,9%), insufficient technical support (38,6%), lack of necessary equipment (37,1%), and low digital literacy among teachers (37,1%).

The findings suggest that physical education teachers actively use digital applications, with fitness trackers and health-monitoring tools being the most popular. While teachers find them less effective for achieving educational and social objectives, they recognize their significant role in tracking pupils' physical development and health status.

Keywords— digital applications, physical education, teachers, pupils, lesson.

I. INTRODUCTION

In today's world, the global community has actively embraced the course of economic digitalization and the informatization of all aspects of human life [1, 2].

Online ISSN 2256-070X

<https://doi.org/10.17770/etr2025vol3.8535>

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Ukrainian society is currently at the stage of active development and implementation of digital technologies across all areas of social relations, including the field of physical culture and sports. The advantages of digital transformation are evident—this enormous leap forward for humanity opens up broad perspectives and opportunities for children, teenagers, youth, and the adult population. The advancement of digitalization in Ukraine in the realm of physical culture and sports plays one of the most significant roles in human and societal life.

According to R. Shchokin and Z. Beleniuk, there is an urgent need to implement a system of digitalization in physical culture and sports. They believe that such a system would help address the following tasks:

- Strengthening transformational leadership, changing mindsets, and enhancing digital potential at the individual level, particularly for participants in the educational process, including teachers, students, and athletes;
- Transforming organizational structure and culture;
- Promoting systemic thinking and the development of integrated approaches to policy-making and the provision of physical fitness and wellness services [3].

To promote the digital space, the Ministry of Youth and Sports of Ukraine is currently paying considerable attention to this issue. A dedicated digitalization sector has been created, leading to the active implementation of sports startups such as: RunAn – a sports tracker designed to reduce injuries and improve running efficiency through running technique control; Gymcerebrum – an artificial intelligence platform with unique computer vision technology, functioning in fitness clubs as a virtual coach; TenniRobo – an innovative table tennis robot that serves as a professional coach, controlled via a mobile application; 12Climb – an interactive climbing wall with thousands of routes controlled via a smartphone, along with an app for tracking training progress; Real Talk Sport – a CRM web system for managing combat sports competitions and the activities of sports federations; Unior F – a sports platform for children, schools, and scouts [4].

Distance learning technologies are a key tool for achieving one of the main goals of educational digitalization—ensuring the continuity of the learning process. These technologies allow for the identification of the specific features of digital application use at the current stage of school physical education development, including personalized learning, remote learning, motivation and engagement of students in physical activities, the creation of educational resources and materials, feedback on the quality of physical education lessons, health and physical condition monitoring, physical development and preparedness assessment, as well as communication and collaboration. This makes our research highly relevant.

The purpose of this study is to examine the attitudes of physical education teachers toward the use of digital

applications in physical education, identifying both the advantages and challenges of their implementation.

II. MATERIALS AND METHODS

The study employed the following scientific methods: analysis and synthesis of literature sources, a questionnaire survey, and mathematical processing of the survey results.

A total of 648 physical education teachers from general secondary education institutions participated in the survey (68.6% men and 31.4% women). The respondents had varying lengths of teaching experience and belonged to different qualification categories. The distribution was as follows:

- 7.14% of physical education teachers held the qualification category “Specialist,” including 8.3% of male and 4.5% of female teachers;
- 18.6% held the second qualification category, comprising 20.8% of men and 13.6% of women;
- 27.1% had obtained the first qualification category based on the results of attestation – 27.1% of male and 27.2% of female teachers respectively;
- 47.1% held the highest qualification category, including 43.8% of men and 54.5% of women.

Regarding teaching experience, the surveyed specialists demonstrated the following distribution:

- 7.14% had 1 to 5 years of experience. Among them, 8.3% were men and 4.5% were women;
- 8.6% of physical education teachers had 6 to 10 years of teaching experience, including 8.3% of male and 9.1% of female respondents;
- 10.0% of respondents had been working in schools for 11 to 20 years, of whom 12.5% were men and 4.5% were women;
- 18.6% had teaching experience ranging from 21 to 25 years. This included 20.8% of men and 13.6% of women;
- 20.0% of teachers reported having 26 to 30 years of experience – 22.9% of men and 13.6% of women;
- 35.7% had been working in schools for more than 30 years, including 27.1% of male and 54.5% of female teachers.

The survey of both physical education teachers and students was conducted using Google Forms, which were distributed through professional communities of physical education teachers and social media platforms such as Facebook, Instagram, and Telegram channels. All participants provided verbal informed consent to take part in the survey, which was indicated at the end of the questionnaire.

III. RESULTS AND DISCUSSION

It was found that the majority of physical education specialists – 62.9% – use various digital devices during physical education lessons. Furthermore, it was revealed that female teachers utilize such devices more frequently than their male counterparts. This is supported by the data:

77.3% of women and 56.2% of men reported using digital tools. An opposite trend is observed among those who do not use digital devices: 13.6% of women and 41.7% of men reported not using any digital applications as auxiliary tools in physical education, representing 32.9% of all respondents.

A small percentage of respondents indicated that they plan to use digital devices in the future. This view is shared by 4.2% of the surveyed teachers, including 2.1% of men and 9.1% of women.

We found that, in general, physical education teachers have been using digital devices in their lessons over the past five years. This was reported by 42.9% of respondents. It was also established that, in terms of gender, female teachers use digital devices during physical education lessons more frequently than male teachers. Specifically, 54.5% of women and 37.5% of men indicated such use.

Since the onset of the COVID-19 pandemic, 7.14% of respondents quickly adapted to the use of digital devices. However, a notable gender difference was observed: 8.3% of male and 4.5% of female teachers reported this adaptation. In addition, 14.3% of physical education specialists began using digital devices only after the introduction of martial law. This was indicated by 10.4% of the surveyed male teachers and 22.7% of female teachers.

A small percentage of respondents indicated that digital applications became an integral part of their teaching experience only in the past academic year. This was reported by 2.1% of male teachers and 4.5% of female teachers.

It is worth noting that, when asked about the reasons for not using digital devices during strict or adaptive quarantine periods, respondents were unable to clearly articulate their answers.

Physical education teachers highlighted varying frequencies in the use of digital devices, applications, and platforms. The majority, 37.1%, reported using them systematically only during online lessons. Female teachers were found to use them more frequently than male teachers: 63.6% of women compared to 25.0% of men. A small proportion, 11.4% of respondents, reported using digital tools very rarely. In this case, a reverse trend was observed – 16.7% of men and 0.0% of women. Occasionally, 10.0% of respondents used digital devices during physical education lessons, with no significant gender differences: 10.4% of men and 9.1% of women. Additionally, 8.6% of respondents reported using digital devices in every lesson. Among them, female teachers again showed higher usage rates than their male counterparts: 12.6% of women versus 6.3% of men. However, 32.95% of respondents did not consider it necessary to use digital devices during lessons, including

41.7% of men and 12.6% of women. These responses raise certain concerns, as they may call into question the effectiveness of conducting physical education lessons during periods of strict quarantine.

Among the various types of digital devices, interactive learning platforms such as Google Classroom, Moodle, and Edmodo are the most commonly used. A total of 67.1% of teachers reported using these platforms. A significant gender difference was observed in the responses: 90.9% of female teachers use them, compared to 56.3% of male teachers. We believe that this disparity may be attributed to the fact that female teachers are more focused on conducting lessons during quarantine restrictions, whereas male teachers were likely referring to in-person learning.

Fitness trackers and fitness bracelets are used by 34.3% of respondents as an important tool for monitoring students' health. Among them, 12.6% are women and 6.3% are men. In addition, 30.0% of respondents use various mobile applications for health monitoring, with 59.1% of women and 16.7% of men reporting their use. We believe that this approach promotes a more conscious evaluation by students of the impact of physical exercise on their health, which is particularly important for students with health impairments.

To effectively prepare for physical education lessons, 25.7% of surveyed respondents watch video tutorials on YouTube channels, use the Ukrainian Online School, and participate in Zoom conferences. These resources are used by 20.8% of male teachers and 36.4% of female teachers. This suggests that physical education teachers, regardless of gender, strive to improve both their teaching skills and the quality of physical education lessons. The lowest percentage was observed among those who use workout mobile applications such as Nike Training Club and Adidas Training – only 2.9% of teachers reported using them, including 2.1% of men and 4.5% of women. This indicates that the vast majority of respondents are unfamiliar with the wide range of digital applications that can support students in learning physical exercise techniques while studying specific sports.

The use of digital devices in physical education during the pandemic and martial law has had a certain impact on the quality of lessons, students' motivation to engage in physical exercise, their physical activity levels, the implementation of individualized approaches, as well as on addressing educational, health-related, and developmental objectives, including the development of physical qualities.

According to a survey of physical education teachers, 31.4% reported that the use of digital devices has a very positive effect on students' motivation to perform physical exercises. Among them, 33.3% were men and 27.3% were women. Additionally, 14.3% of respondents believe that the impact is extremely positive. However, 31.4% of

respondents consider that students' motivation to engage in physical activity is not influenced by the use or non-use of digital applications during lessons, perceiving the effect as neutral. This opinion is shared by 25.0% of male teachers and 45.5% of female teachers. Furthermore, 14.3% of teachers are convinced that digitalization has a negative impact on student motivation, as students tend to use mobile phones and applications in a way that distracts them through virtual physical activities. This view was expressed by 16.7% of men and 9.1% of women. An extremely negative impact was noted by 8.6% of respondents, with little difference in opinion between genders: 8.3% of men and 9.1% of women shared this perspective.

We found that 32.9% of the surveyed teachers believe that the use of digital applications during physical education lessons significantly contributes to the implementation of an individualized approach to students. This is confirmed by 31.3% of men and 36.4% of women. A further 52.9% of respondents believe that there is partial support from digital tools in this regard. However, 8.3% of men and 4.5% of women disagreed with this view. Additionally, 7.1% of the surveyed teachers were unable to provide an answer to this question.

A slightly different situation was found regarding the impact of digital applications for monitoring students' physical activity and health. Physical education teachers believe that digital applications, such as fitness trackers and bracelets, can help both teachers and students track physical activity during lessons and monitor students' health. A total of 50.0% of respondents are confident in the effectiveness of digital applications. There is a significant difference between the responses of men and women: 35.4% of men and 81.8% of women believe that these applications are highly effective.

The survey of physical education teachers revealed that the use of digital applications in physical education helps teachers save time on explanations and demonstrating the technique for exercises. This was affirmed by 64.3% of the surveyed teachers. Additionally, the use of digital applications helps implement an individualized approach to students, as stated by 45.7% of respondents. Furthermore, the use of digital applications allows for the integration of other subjects into physical education and the development of students' information and communication competencies, according to 41.2% of teachers.

One in three physical education teachers is convinced that the use of digital applications helps develop students' research skills, with 12.5% of men and 22.7% of women sharing this opinion. For 10.0% of teachers, digital applications allow for a deeper immersion in the study of the material. The opinions of men and women on this issue are nearly identical: 10.4% of men and 9.1% of women agree.

However, 7.1% of respondents believe that digital applications distract students from completing educational tasks. Moreover, 4.3% of respondents think that the digitalization of physical education interferes with the teacher's educational activities. This was noted by 4.2% of men and 4.5% of women.

It is worth noting that physical education teachers highlighted both the advantages and disadvantages of using digital devices during PE lessons. The main advantage mentioned by the specialists was access to a wide range of educational materials, as noted by 47.1% of the teachers.

During the interviews, teachers pointed out that modern printed materials do not devote enough attention to the subject of physical education, resulting in a lack of methodological support for conducting PE lessons. Therefore, when preparing for PE classes, teachers often have to search for the necessary materials online on their own. Female teachers tend to use online resources more frequently than their male counterparts (81.8% compared to 31.3%, respectively).

Among the advantages, teachers noted that the use of digital applications enhances the individual approach to students, as agreed by 32.9% of respondents. It is also worth mentioning that 20.0% of physical education teachers believe that the digitalization of physical education increases students' motivation during lessons.

In addition, 17.1% of teachers – including 14.6% of men and 22.7% of women – believe that digital applications help track students' learning progress, particularly in terms of the development of physical abilities.

We found that 15.7% of teachers used digital devices to improve communication with students and their parents, especially during periods of remote or blended learning. Teachers typically do this through Viber groups. Male teachers communicate with students or parents less frequently than female teachers, as indicated by 6.3% of men and 36.4% of women (fig. 1).

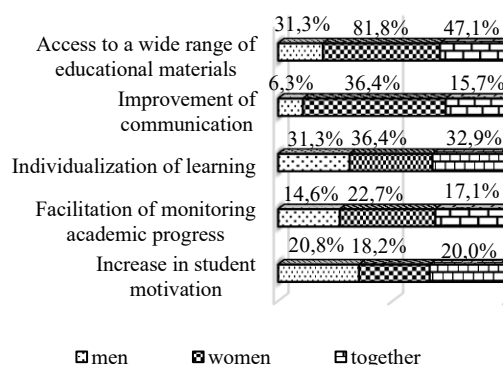


Fig. 1. Advantages of using digital applications in physical education, %.

During the survey, physical education teachers emphasized certain challenges they faced while using digital applications in their teaching. The main ones are as follows:

- Lack of time for preparation and integration of digital tools into PE lessons – reported by 62.9% of surveyed teachers. Broken down by gender: 41.2% of male teachers and 95.5% of female teachers;

- Difficulties integrating applications into the educational process – 71.4% of physical education teachers. This was highlighted by 58.3% of men and 95.5% of women;

- Insufficient technical support for PE lessons – 38.6% of all respondents, including 37.5% of male and 40.9% of female teachers;

- Lack of necessary equipment – reported by 37.1% of schools. This was noted by 20.8% of male teachers and 72.7% of female teachers;

- Low level of personal digital literacy – 37.1% of surveyed teachers, including 33.3% of men and 45.5% of women;

- Low level of students' digital literacy – 14.3%. According to 16.7% of male and 9.1% of female physical education teachers.

In light of these challenges, physical education teachers emphasized the need for additional training in digital literacy and the development of methodological guidelines for using digital applications in physical education (PE). This view is shared by 44.3% of respondents. The opinions of male and female teachers on this issue are nearly identical: 41.7% of men and 50.0% of women. Additionally, 31.4% of respondents believe that such training is needed, but not urgently. Meanwhile, 17.1% think that there is no need for specific measures to improve digital literacy, and 7.1% completely reject the necessity of such measures.

Despite the generally positive impact of digital applications, every third respondent noted that their use reduces the quality of physical education lessons. However, 12.9% of teachers believe otherwise and emphasize a significant improvement in lesson quality. This view is shared by 12.5% of male and 13.6% of female teachers. Additionally, 10.0% of teachers reported a moderate improvement in PE lessons thanks to digital applications. Meanwhile, 17.1% of teachers expressed a neutral opinion regarding the use of digital applications – including 20.8% of men and 9.1% of women.

We asked physical education teachers about the impact of digital applications on achieving the goals of PE lessons – educational, health-related, and developmental. A total of 31.4% of teachers believe that digital applications negatively affect the achievement of educational goals.

The opinions differ significantly between male and female teachers: 41.7% of men and only 9.1% of women. Additionally, 30.0% of respondents noted a somewhat negative effect. On the other hand, 7.1% of respondents believe that digital applications help achieve educational goals. Another 30.0% think that digital tools help more than hinder in reaching educational objectives, with a notable difference between genders: 68.2% of women compared to 12.5% of men.

Regarding the impact of digital applications on achieving health-related goals, teachers' responses were significantly more positive compared to educational goals. A total of 41.4% of teachers believe that digital applications improve the achievement of health-related goals during lessons, with a higher percentage among women (50%) compared to men (37.5%).

31.4% of respondents think that digital applications somewhat help in achieving health-related goals. Teachers believe that the use of fitness trackers for health will encourage students to be more mindful of their health. There is a notable difference between male and female teachers on this: 45.5% of women and 24.0% of men agree with this.

15.7% of respondents are convinced that digital applications do not help achieve educational goals during physical education lessons. Men have a more negative attitude towards this, with 20.8% of men compared to 4.5% of women holding this view. 8.3% of men express a strongly negative opinion about using digital applications to achieve health-related goals. Additionally, 8.3% of men had difficulty providing a clear answer to this question.

45.7% of teachers consider the use of digital applications ineffective for achieving developmental goals during PE lessons, as they do not contribute to the development of moral-volitional qualities or the formation of teamwork skills. Women are more strongly convinced of this: 54.5% of women compared to 41.7% of men. However, 37.5% of men strongly reject the use of digital applications to achieve developmental goals. We also found that nearly one in five respondents (22.9%) has a more positive attitude towards using digital applications for developmental goals than negative, with a significant difference between men and women: 16.7% of men and 36.4% of women. Only 5.7% of teachers are firmly convinced of the need to use digital applications to achieve developmental goals.

When asked the question, "Do digital applications improve tracking the development of students' physical abilities?" 48.6% of respondents answered positively. There is a slight difference in responses between men and women: more women (68.2%) are convinced of this than men (39.6%). However, 15.7% of teachers disagree with this, with responses from both genders being almost identical: 16.7% of men and 13.6% of women. Additionally, 8.6% of teachers have a negative attitude

towards using digital applications for monitoring the development of students' physical abilities.

Thus, our study confirms the conclusions of other Ukrainian scholars [5, 6, 7, 8] regarding the relevance of using digital devices in physical education, as well as the research of foreign scientists on the advantages and challenges of integrating digital technologies into the educational process [9, 10] and the impact of digitalization on physical activity [11, 12]. It is worth noting that our research complements the conclusions of Australian scholars [13] on the importance of using digital applications to enhance motivation for physical education, as well as our previous studies on monitoring physical condition through digital technologies [14]. Moreover, our study [15] emphasizes the importance of using digital devices as an alternative means of supporting physical activity during the Covid-19 pandemic and complements the findings of foreign researchers [16, 17, 18, 19, 20].

It has also been established that the results of our survey of physical education teachers in Ukraine align with the findings of foreign researchers, who emphasize the readiness of physical education teachers to apply digital technologies in physical education, provided that the teachers' perception of the lesson as a practical discipline is not compromised [21]; the importance of using digital devices to enhance student motivation and physical activity [22]; as well as the advantages and challenges of using digital technologies in physical education practice [23, 24].

IV. CONCLUSION

Thus, the survey of physical education teachers of different genders, qualification categories, and teaching experience allows us to conclude that, in today's conditions, the overwhelming majority of physical education teachers use digital devices and applications during physical education lessons. Most teachers do this in the context of distance learning.

Among the full range of digital applications, the most popular among physical education teachers are fitness trackers and applications that allow monitoring health levels.

It was established that physical education teachers consider digital applications ineffective for achieving developmental goals, less effective for educational goals, and the most effective tools for tracking the development of physical qualities and students' health.

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Methods of Forming Electronic Resource Collections of Academic Libraries in a Digital Educational Environment, Criteria for Selecting Electronic Resources

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Abstract—In today's digital educational landscape, the development of electronic resource collections in academic libraries holds significant importance. These collections not only offer extensive scientific information but also facilitate interactive and distance learning processes. By providing rapid and convenient access to educational materials through digital platforms, databases, and e-books, electronic resource collections empower users to efficiently locate and utilize information. This advancement is poised to elevate the scientific and creative endeavors of both students and academic staff, thereby enhancing the overall quality and effectiveness of education. The primary objective of this study is to analyze the process of developing electronic resource collections for academic libraries within the context of the digital educational environment. It seeks to explore the scientific and practical dimensions involved in selecting, acquiring, and subscribing to electronic resources. Furthermore, the study aims to identify the criteria and methodologies employed in this process, assess their effectiveness, and formulate recommendations for improvement. To conduct this research, various methods were examined and analyzed. To ensure comprehensive coverage and convenience for respondents, the online survey method was selected as the principal research approach. Four distinct surveys were designed to address different facets of the research objectives. These surveys focused on the selection criteria influencing decisions regarding the procurement of electronic resources, the strategies employed by specialists in forming electronic resource collections, and the criteria used to evaluate their effectiveness. All these aspects were thoroughly investigated and incorporated into the research. Based on the findings derived from this study, a series of

recommendations were formulated. Proposals were developed to tackle the challenges associated with the selection of electronic resources and the enhancement of their collections in university libraries across Uzbekistan.

Keywords—Academic library, consortium, database, electronic resource.

I. INTRODUCTION

In the digital age, academic libraries are facing challenges related to the transition from traditional print collections to electronic resources. This shift is driven by the need to provide users with convenient and important information in various formats, such as e-books, e-journals, and online databases [1],[2]. A library's collection is the cumulative result of acquiring, organizing, storing, and making resources openly available to users. The library's collection serves users' needs by providing resources for education, research, leisure, and information dissemination. According to Tiurkedzhy et al., modern practices in creating electronic libraries demonstrate insufficient access to content [3]. The authors emphasize the necessity of processes related to optimizing and promoting resources available in the library, but this study did not focus on analyzing search queries as one of the methods to ensure access to content. On the other hand, Berdykulova et al.'s research discusses the transition of traditional university education to the digital sphere [4]. In the study by Habibi, Mohd Faiz Mohd, and Sofwan, the functioning of digital libraries during the coronavirus pandemic was examined, with the authors proposing solutions to problems related to school closures and the inability to conduct offline learning [5].

Online ISSN 2256-070X

<https://doi.org/10.17770/etr2025vol3.8513>

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Akanova, Kozhasheva, and others have conducted scientific research on the systemic-functional methods of modeling electronic libraries. According to them, these methods are based on the interaction between key elements: function, structure, technologies, and management [6],[7].

Professor Ganiyeva B.I., in her article titled "The Development of Digital Libraries and Their Impact on Improving the Rankings of Higher Education Institutions," has elaborated on the concepts of "electronic," "digital," and "virtual" libraries. She has also addressed the impact of information library institutions on improving the rankings of higher education institutions [8]. Abdymanapov, Ronzhes, Tammara, and others, in their research, have stated that an academic electronic library is affiliated with a specific educational institution and serves the purpose of providing teachers and students with electronic materials for learning and research [9], [10], [11].

The main goal of this research is to identify and evaluate the criteria and methods used in forming and managing electronic resource collections, as well as to develop recommendations for improving the efficiency and quality of electronic resource collections in academic libraries in Uzbekistan.

II. MATERIALS AND METHODS

A. *Methods of Forming electronic resources in academic libraries*

The development of information and communication technologies has significantly changed how libraries acquire information resources and organize data. Libraries use various methods to purchase necessary electronic resources. However, L. Benny emphasizes that electronic resources can be acquired through purchase, subscription, or consortium agreements [12]. She also notes that the most widely used method for forming electronic resource collections in many libraries is subscribing to electronic resources. Similarly, according to F. Ifeoma and Achebe, the most effective way to provide access to e-books/journals in university libraries is through subscriptions to online databases that allow remote access via the internet [13]. Some libraries have successfully purchased electronic resources through consortia, benefiting from bulk discounts. Consortia are another way for libraries to learn about available electronic resources.

According to L. Creibaum and S. Holloway, there are four methods of forming electronic resources in academic libraries [14]:

Subscription: This is a method of obtaining a license to access information resources for an agreed period of time.

Purchase: Acquiring information resources through direct purchase.

Consortium: This is a cooperative association of libraries that coordinates resources. When many products are purchased through a consortium, discounts may be available, and there may be additional discounts for repeat

customers. Libraries that already own parts of the offered product may also benefit from reduced prices.

Open Access: Free and open online access to electronic resources. Several reputable publishers exist that provide free access to authentic and valuable content.

Analyzing users, selection policy, managing acquisitions, library staff, user community, weeding and preservation, collection evaluation, and resource sharing are considered functional factors of library collection management [15]. This is illustrated in "Fig. 1".

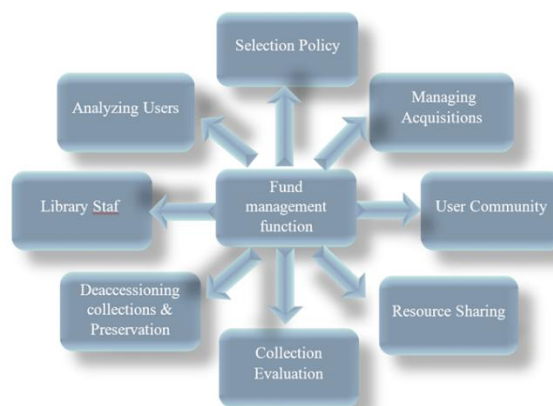


Fig. 1. Functional Aspects of Collection Formation/Management

Any library—whether academic, public, or school libraries (state, private, charter, independent, or international)—must have a detailed policy that governs the selection, rejection, or cancellation and review of library resources. The most critical policy is the selection policy, which is regularly reviewed and updated, and is familiar to all members of the library staff.

The selection of information resources is a fundamental function of library collection development, and the primary goal of the selection decision for any format remains the same: to meet the needs of users. D.A. Cabonero and L.B. Mayrena have emphasized in their articles that selection is the heart of collection development[16]. Selection is the first essential step in the acquisition process. Information materials are chosen based on their usefulness for a specific group of readers. This is because the level of satisfaction a reader finds in a library is directly dependent on the resources available in the library[17]. With the emergence of electronic resources, the job responsibilities of library professionals managing collections have significantly changed.

III. RESULTS AND DISCUSSION

A. *Selection of Electronic Resources and Research Results*

The concept of electronic resources refers to information sources that are studied, processed, and redesigned using modern information and communication technology (ICT) tools. They are often stored in cyberspace in the most precise and compact form and can

be accessed simultaneously by a wide audience from an unlimited number of locations.

The general types of electronic resources under consideration include the following:

- Databases,
- Continuing education websites,
- E-books/monographs,
- Full-text electronic journals,
- Internet websites,
- Reference tools,
- Teaching and learning materials, and so on.

In addition to collection development policies, the selection of electronic resources must align with the library's primary goals; otherwise, it may lead to the creation of an aimless and unnecessary electronic collection. In his article titled "The Changing Roles of Library Professionals and Bibliographers in the Era of Electronic Resources," Welch, T.M. emphasizes that staff have used traditional selection criteria such as quality, relevance, accessibility, and price to choose new materials for the purpose of collection development [18].

Similarly, as T.L. Davis has pointed out, the most essential criteria in traditional selection include evaluating the reputation of authors and publishers, assessing the level and depth of content, and considering special formats or features that add value to the title [19]. For electronic resources, these criteria quickly evolve into evaluating the involvement of other parties in the product's creation, ensuring the availability of accurate content, and confirming that the product performs as expected. W.B. Edgar examined the unique characteristics of collection content and noted that these characteristics can be used to guide the selection process.

The more features a resource has—such as subject, sub-topic, publication date, or format—the more precisely it can be selected, and vice versa [20].

This means that greater specificity is required to ensure that ideas within a body of knowledge are included in the designated collection.

In their research work titled "Managing Electronic Resources in Libraries: Research and Practice," H. Yu and S. Breivold Edgers confirm that librarians must now address new challenges as part of the selection and management processes, such as ensuring easy and quick access for users, evaluating persistent content, and resolving technological and legal issues [21].

In forming a quality collection, materials are evaluated based on specific criteria. It is not necessary for every element to fully meet all the criteria. Based on our research, we have divided all the criteria adopted for resource evaluation into three groups: *primary*, *secondary* and *special criteria for electronic information sources* "Fig.2". Through these criteria, it has been determined how materials can align with the collection and increase the efficiency of their use. Additionally, it is crucial to consider these criteria when selecting electronic resources to ensure their quality and relevance

to the intended purpose. Research has shown that applying the right criteria can make the collection more efficient and beneficial.

Electronic resources, unlike printed materials and multimedia materials related to books, often do not become the property of the library.

In many cases, libraries only acquire access rights to electronic resources, not ownership, which is achieved through subscription based on agreed license terms. Therefore, the team established for resource selection should include not only information technology specialists but also individuals with legal expertise. Additionally, the sharp increase in subscription prices for databases has led libraries to collaborate on purchasing. Cooperative purchasing is carried out in the form of a consortium.

As other authors have observed, while acknowledging the challenges posed by electronic resources, IFLA has noted that electronic resources introduce a number of barriers not encountered with traditional library materials.

In addition to the criteria applied to analog materials, electronic publications raise complex issues related to licensing, access, networking, pricing, intellectual property rights, and rapidly changing technologies and standards.

As H. Yu and S. Breivold Edgers have pointed out, when working with electronic resources, the librarian responsible for collection management cannot make an independent decision to purchase an electronic resource and must work closely with other library departments to evaluate the suitability of the resource. Typically, this involves consulting with staff responsible for technical systems and services, acquisitions, resource identification (cataloging and access), contract negotiation and licensing, and user support.

To involve users in collection development, the library can explore methods to gather feedback from its users regarding electronic resources. This may include feedback on potential new sources as well as existing resources. The library should inform users about new literature and services, as well as temporary issues that may arise with access to electronic resources. Detailed information about the resource is required to determine whether the electronic resource fits the library's collection and to help identify the actual and hidden costs of purchasing, storing, maintaining, and other related issues. In their research article titled "*Developing an Electronic Resources Collection: A Survey of Current Practices in Academic Libraries*," R. Flatley and K. Prock propose a five-step process for collecting electronic (or "digital") materials, which includes gathering content information, evaluating information content, organizing content, creating electronic resource collections, and preserving them [22].

In academic libraries, organizing an electronic resources collection requires a strategic approach that includes thorough needs assessment, collaboration models, trial usage programs, and continuous evaluation

processes. By focusing on the relevance of content, frequency of updates, accessibility, cost-effectiveness, and the reputation of the vendor—and adhering to clearly defined selection criteria—libraries can create robust electronic collections that meet the evolving needs of their academic communities in the digital learning environment. To achieve this goal, an online survey

involving 51 librarians from 8 university libraries was conducted to explore four methods of forming electronic resource collections. The data was tabulated and analyzed using basic statistics (average values).

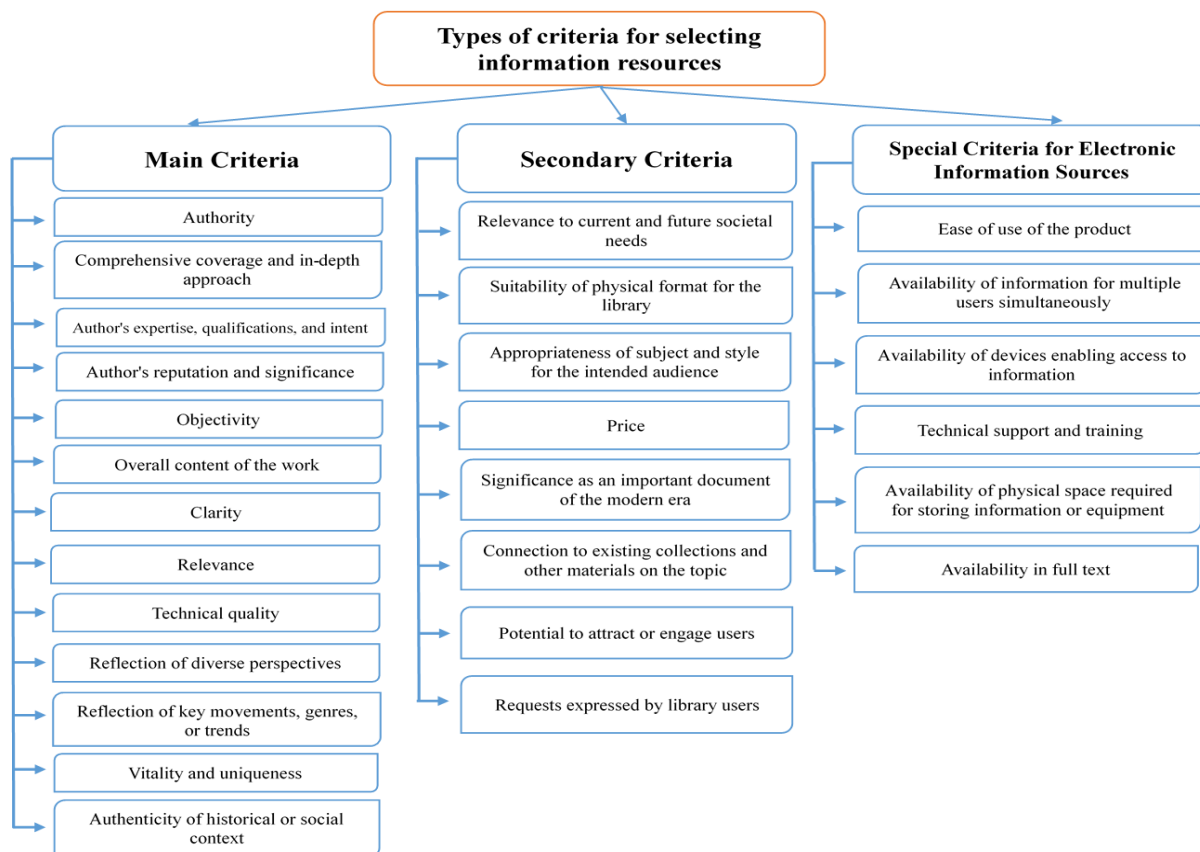


Fig. 2.

Types of Criteria for Selecting and Acquiring Information Resources.

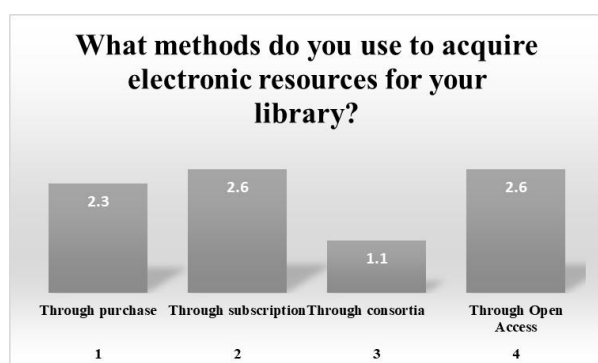


Fig. 3. Methods of forming electronic resources in the studied academic libraries.

The analysis results “Fig. 3” showed that forming electronic resource collections through consortia scored an average of 1.1, while subscriptions and open internet sources scored up to 2.6. These values were assessed using a 3-point rating scale (always = 3, sometimes = 2,

never = 1). Electronic resources must always be available, whether online or offline, to meet the needs of staff, students, researchers, and other library users.

B. Selection of Electronic Resources

From the primary and secondary criteria mentioned above for purchasing electronic resources, the 8 most important criteria suitable for scientific and academic library collections were selected. Based on these criteria, an online survey was conducted among librarians from 8 university information resource centers. The survey involved 51 staff members responsible for technical systems and services, acquisitions, resource identification (cataloging), contracts and licensing, and user support.

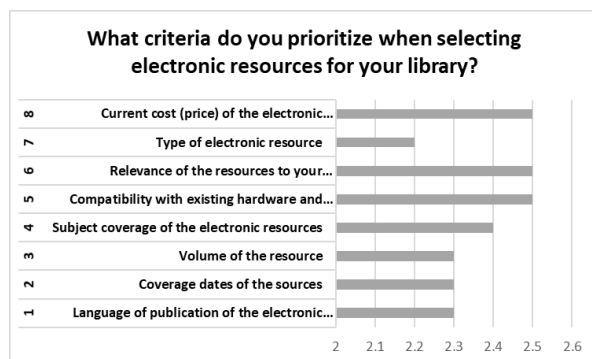


Fig. 4. Criteria for selecting electronic resources in the acquisition process.

Additionally, the overall average data “Fig. 4” showed that compatibility with existing hardware and software, the relevance of the resource to library users, and the current price of the resource (average = 2.5) received the highest scores, while the type of electronic resource (average = 2.2) received the lowest score among the criteria considered by libraries when selecting electronic resources. These values were assessed using a 3-point rating scale (always = 3, sometimes = 2, never = 1). Responses from the eight surveyed university libraries indicated that libraries evaluate resources in printed materials based on criteria such as price, content, location, and others. However, for electronic resources, librarians place greater emphasis on criteria such as subject relevance, authenticity of information, accessibility, price, the reputation of the vendor, and various technical factors. University librarians use various criteria when selecting electronic resources to ensure they choose and purchase the best options for their libraries.

C. Issues in Selecting and Acquiring Electronic Resources

Selecting and acquiring electronic resources in academic libraries can lead to a number of challenges that may affect collection development and user access. The main issues include:

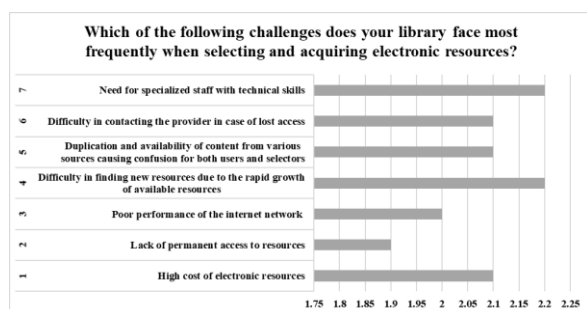


Fig. 5. Responses to challenges faced by your library in selecting and acquiring electronic resources.

The data presented in “Fig. 5” reflects the challenges faced by university libraries in Uzbekistan in forming electronic resource collections. This data is based on responses from librarians who participated in the survey, with the average values of the results ranging from a low

of 1.9 to a high of 2.2, calculated on a 3-point scale. These numbers indicate that for the majority of librarians, the process of forming electronic resource collections is highly complex and requires serious attention and improvement. Therefore, clear strategies and supportive measures are necessary to address these challenges. It can be emphasized that this data holds significant importance for improving the development and quality of use of electronic resources in university libraries.

IV. RECOMMENDATIONS

Based on the results of the survey and the analysis, the following recommendations are suggested to ensure a smooth process for selecting and purchasing electronic resources in university libraries in Uzbekistan. These recommendations aim to support the scientific, informational, and technological development of library services and to fully and effectively meet the information needs of users.

- Analyze the scientific and educational needs of students, professors, and researchers.
- Identify the most in-demand databases by field (for example, JSTOR, ScienceDirect, SpringerLink, IEEE Xplore, and others).
- Determine the most necessary electronic resources through surveys among users.
- Use statistics on how often electronic resources are used to identify the most useful platforms.
- Analyze how electronic resources in scientific databases impact the scientific work of universities (for example, count how many articles, dissertations, or research papers are created based on these resources).
- Study and apply international licensing procedures for using electronic resources.
- Allocate financial support from the organization’s budget to train staff responsible for developing electronic collections in university libraries in Uzbekistan.
- Create a consortium among Uzbek libraries and make effective use of discounts offered by the consortium.
- Train and retrain library staff in technical skills and software. This is important for solving any technical problems that may occur when using electronic resources.

CONCLUSION

The article explores the methods of forming electronic resources in academic libraries within the digital education environment, emphasizing the criteria for selecting high-quality resources. The primary goal of this research was to thoroughly analyze the process of creating electronic resource collections for academic libraries, as well as to study the scientific and practical

aspects of selecting, purchasing, and subscribing to electronic resources. Additionally, identifying the criteria and methods used in this process, evaluating their effectiveness, and developing recommendations for improvement are key focuses of the study. This ensures the provision of high-quality, relevant, and modern information resources. The article highlights the main approaches to developing electronic collections, including institutional repositories, subscription-based databases, and open-access resources. The selection policy is based on factors such as alignment with academic programs, reliability, accessibility, and cost-effectiveness. Furthermore, the article examines common challenges in selecting and purchasing electronic resources, such as budget constraints, licensing issues, and ensuring long-term usability. By addressing these challenges, academic libraries can expand their electronic collections to better support education and research. According to the research findings, libraries primarily acquire electronic resources through subscriptions and individual purchases. None of the libraries studied in the research formed a consortium with other libraries. Establishing a consortium would enable libraries to pool resources, share scientific and literary materials, and collaboratively purchase new books, journals, and electronic resources. This would reduce individual costs for each library and allow for more efficient use of resources. Based on the research results, recommendations were developed for university libraries in Uzbekistan regarding the selection and development of electronic resource collections. These recommendations aim to further improve and enhance the effectiveness of electronic resource collections.

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Basics of Media Literacy Formation for Library Specialists

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Abstract—In the context of information abundance characteristic of the digital age, media education and libraries play a key role in the development of media literacy among the population. By interacting with each other, they help people not only find the necessary information but also critically evaluate it, use it wisely, and create their own content, transforming libraries into modern centers of knowledge and learning.

Media education is a field of education that focuses on the study and use of various types of media for learning purposes. In the context of modern information realities, the training of library specialists is unthinkable without the development of deep media literacy.

The set of competencies that make up the content of media and information literacy enables future specialists to operate effectively in the information space and provide high-quality library services. The aim of the study is to systematize theoretical knowledge and empirical data in the process of developing media literacy among library specialists in order to identify the most effective methods and strategies for enhancing their media competence.

The proposed methods include interactive learning, project-based learning, collaborative learning, the use of digital technologies, modeling real work situations, critical analysis of media content, and scientific research activities. The essence of these methods lies in developing specialists' ability to work effectively in the modern information space, critically evaluate media content, use digital technologies, and educate users.

Keywords: Education, librarians, media literacy, methods, strategies.

I. INTRODUCTION

In the era of the digital revolution, when information has become more accessible than ever, media education and libraries play a key role in shaping society's information literacy. These two fields, seemingly different in nature and function, are becoming increasingly interconnected in the context of modern education and cultural development [1]. Libraries are no longer just repositories of books; they are transforming into educational centers that facilitate the mastery of media technologies and the critical analysis of information [2].

Modern research demonstrates a trend toward integrating the concepts of media literacy, information literacy, and digital literacy, which necessitates a reconsideration of traditional approaches to training library specialists. International experience from developed countries such as Canada [3], France [4], the United States [5], Australia, and Finland [6] shows that successful media education in libraries is based on the use of innovative methodologies, digital tools, and interactive technologies.

The scientific research is conducted to improve the work of information and library institutions, develop and study methods for fostering information culture in the field of media education, analyze the use of media content, examine the role of media competence among library specialists, as well as explore methods for teaching media literacy to future library professionals. The methods of media education for librarians are aimed at integrating theory and practice, developing digital and analytical skills, and training them to work with modern technologies and audiences. Based on these methods, the following

Online ISSN 2256-070X

<https://doi.org/10.17770/etr2025vol3.8518>

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strategies are developed: creating professional communities, integrating digital technologies, continuous research and self-education, developing practical skills, collaborating with external partners, analyzing and evaluating one's own work, and conducting information campaigns. These strategies will help librarians not only adapt to modern conditions but also effectively fulfill their educational role, contributing to the development of media literacy among users.

Media education helps people become more informed and critically thinking consumers of information, as well as develop skills in media content creation [7]. Moreover, media education focuses on teaching skills related to working with various media formats, including reading, viewing, listening, and creating media content. This involves critical analysis of information, assessing the reliability of sources, and understanding media technologies and their impact on society [8].

Media education also contributes to the transformation of libraries, turning them into modern centers of knowledge and learning, where people can not only access information but also develop media-related skills, participate in educational programs, and use new technologies for self-development.

In international practice, media education is also considered an integral part of information literacy. According to the MediaSmarts concept, media literacy, information literacy, and digital literacy are interconnected, forming a comprehensive concept of digital media literacy [3]. The UNESCO program [9] aims to develop media competencies, ensuring that users acquire the necessary skills to work with information in a digital environment.

Media literacy, as a separate subject, can be studied as part of the professional training of specialists such as journalists, radio and television workers, editors, PR managers, diplomats, and lawyers [10].

This study analyzes existing theoretical approaches and practical methods for developing media literacy within the general training of library science students and among library specialists. Special attention is given to international experience in media education and the adaptation of effective strategies to the context of Uzbekistan. The main goal of the research is to identify the most effective methodologies and develop recommendations for their implementation in the educational process of librarians.

II. MATERIALS AND METHODS

The analysis of modern research in the field of media literacy demonstrates a trend toward the integration of previously separate concepts. The Canadian organization MediaSmarts, a leader in this field, emphasizes that "information literacy," "media literacy," and "digital literacy" are becoming increasingly interdependent, leading to the formation of the concept of "digital media literacy" [3].

This concept, along with the UNESCO curriculum [9], which is aimed at developing media and information literacy, seeks to equip users with critical analysis skills and the ability to work effectively with information in the

modern media environment. Despite differences in their approaches, both concepts strive to develop users' abilities to critically assess and process information.

The essence of this concept evolves from a simple sum of the mentioned fields into a comprehensive framework that incorporates information, media, and technology as its integral components, reflecting the goals of media and information literacy.

In the field of pedagogy and teaching methodology, several key approaches to developing media literacy are highlighted, such as:

- Project method
- Collaborative learning
- Application of digital technologies
- Modeling real-life situations
- Critical analysis of media content
- Interactive method.

A.V. Fedorov [7] conceptualizes media education as an educational paradigm aimed at exploring and applying diverse media technologies within the educational and training process. This concept is empirically supported by the research of Professor Ganieva B. I., who focuses on developing critical thinking and media competencies through media education [2].

At the same time, Makarova N. Ya. and Yarnykh V. [11] emphasize that media education is aimed at teaching media literacy, which includes skills in analyzing, perceiving, and creating media content. This aligns with the definition provided by Olefir S. V. [12], according to which media literacy encompasses a set of skills, including the critical analysis of informational materials, the evaluation of source reliability, and an understanding of the principles of media technologies and their sociocultural impact.

However, in their article, Julien Bourdet and Amélie Barrio [13] highlight that media education facilitates the modernization of libraries, transforming them into modern educational spaces where users can develop media skills, engage in educational programs, and utilize new technologies for personal development.

The use of innovative technologies and the provision of fast and easy access to services for society is a key function of libraries. This is directly related to the fact that library specialists, possessing expert competencies in the field of information literacy, perform a crucial educational function, contributing to the development of relevant skills among learners. This, in turn, ensures the effective use of innovative technologies and access to services, as noted in the works of I. V. Zhilavskaya, Mullins, K., & Boyd-Byrnes, M. K. [14], [15].

In the educational manual "Think Critically, Click Wisely!", key outcomes and elements of media and digital information literacy are presented [9].

TABLE 1. INFORMATION LITERACY

Information Literacy	Identify and articulate information needs
	Locate and know how to access information
	Receive information
	Structure information

	Use information ethically
	Disseminate information
	Use ICT skills to process information

TABLE 2. MEDIA LITERACY

Media Literacy	Understand the role and functions of media and internet companies in democratic societies
	Understand the conditions in which the media can realize their functions
	Critically evaluate media content in the context of the function's media
	Use media for self-expression and democratic participation
	Possess the skills necessary for creating user-generated content (including ICT skills)

TABLE 3. DIGITAL LITERACY

Digital Literacy	Use digital tools
	Understand what digital identity
	Know about digital rights
	Assess risks associated with artificial intelligence technologies
	Develop digital communication skills
	Possess skills in the field of digital health
	Apply digital security and protection tools

Each of these approaches has its own advantages and is suitable for different learning contexts and for understanding the role of literacies in the modern information society. However, most international experts convened by UNESCO emphasize the close interconnection, and in some cases the inseparability, of information, media, and digital technologies [9].

However, most international experts convened by UNESCO point to the close interconnection, and sometimes even the inseparability, of information, media, and digital technologies. Specialists in different countries around the world use the following terminology:

- Media Literacy
- Information Literacy
- Expression and Information Literacy
- Library Literacy
- News Literacy
- Social Media Literacy
- Critical Literacy
- Print Media Literacy
- Computer Literacy
- Internet Literacy
- Digital Literacy
- Artificial Intelligence Literacy.

Min Shi and I. V. Zhilavskaya [6], analyzing the experience of developed countries in media education in

libraries, show that the most interesting and effective practices can be found in countries such as Canada, the USA, Australia, and Finland. Each of these countries actively develops and improves its approaches to media education in libraries.

In the development of media literacy and media culture, public libraries in Australia provide dedicated media zones. The city library of Adelaide hosts a media lab where users have access to the latest technologies, including a Sony HD video camera, Intuos Pro Wacom, software from the Adobe Creative Cloud suite, Avid Pro Tools, Sibelius, and more. This enables them to fully engage in filming, editing, animation creation, and photo editing, as well as develop their own content in public and regional libraries.

Research on media education [2] highlights the active role of the Finnish Library Association in advancing media education in Finland. The association implements innovative methods and emphasizes the quality of media education in public libraries. In small municipalities, libraries often serve as the main cultural hubs for children and young people, organizing various events such as theatrical performances, storytelling sessions, film screenings, and exhibitions. Through these activities, libraries ensure safe access to new media and the internet. To effectively foster media literacy among users, librarians must develop competencies and professional skills in teaching information and media literacy.

In Australian universities and libraries [6], workshops are held on using digital tools for fact-checking. Participants learn to work with platforms such as FactCheck.org and analyze media content using technologies like reverse image search.

In the research by Cho, Y., and Brown, C. [5], the project-based method, which involves students developing projects such as media content creation, thematic collections, and virtual exhibitions, is analyzed as an effective learning tool. The authors also emphasize the need for information campaigns to enhance media literacy among library users.

In the United States, the project-based learning method is applied in various forms. Universities and colleges use this approach to develop environmental programs, enhance students' social skills, implement innovative technologies, establish connections between education and the labor market, and teach foreign languages. Some scholars even argue that the modern world can be viewed as a collection of diverse projects. A significant portion of not only educational but also labor and socially significant activities in the U.S. is carried out through project implementation [5].

Zanin-Yost, A., and Freie, C. propose a methodological approach that integrates Berman's critical literacy with information and media literacy to foster collaborative learning and enhance students' critical thinking skills within the context of their subject area [16].

The use of digital technologies encompasses online platforms and simulators for hands-on training in searching, analyzing, and evaluating information. It also

includes virtual tours and webinars led by experts in media and library sciences.

Gong, L. [17] notes in their research that data visualization has become widely adopted in the educational practices of Chinese universities, providing a clear and accessible representation of students' research findings.

Modeling real-work situations within media education includes the following practice-oriented approaches:

- Hands-on activities in libraries aimed at assisting users in working with media content, fostering skills in audience engagement and applying media literacy in real-world contexts.
- Organizing educational events, such as media literacy lessons for schoolchildren or lectures for older generations, enabling the adaptation of media literacy to various age and social groups.

A successful example of implementing such approaches can be seen in Canadian universities, where students have the opportunity to master professional equipment in virtual studios and laboratories. This ensures the development of practical skills for working in the media environment and prepares them for professional careers.

Critical analysis of media content involves discussions and debates on topics such as fake news, propaganda, and the influence of media on society. It also includes analytical sessions where students learn to identify manipulative techniques in media texts.

Media literacy educational programs implemented in Canadian universities and colleges serve as an example of an effective methodological approach. In his research, Badke, W. [4] emphasizes that students acquire skills in critically analyzing various types of media content, including news materials, advertisements, and other media formats. These courses focus on identifying hidden messages, manipulative techniques, and stereotypes, fostering critical and thoughtful media consumption among learners.

The interactive method involves students participating in research related to media education and user information behavior. Specifically, this includes writing essays and academic papers on the role of libraries in developing media literacy.

According to A. B. Kirkland [3], Canadian libraries demonstrate an effective methodological approach to media education by developing and implementing a variety of programs, ranging from workshops on media content creation to seminars on critical information analysis. To ensure the effectiveness of these programs, systematic evaluations are conducted, with adjustments made as needed.

III. RESULTS AND DISCUSSION

To study the impact of methods and strategies for developing media literacy, a survey and analysis were conducted among students in Uzbekistan specializing in library sciences. The study assessed the level of media literacy among both library science students and practicing librarians.

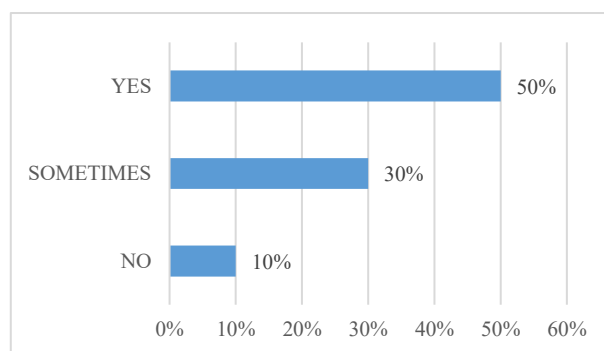


Fig.1. Application of digital technologies.

The analysis of responses from students studying library science revealed an insufficient level of proficiency in digital technologies, online platforms, and simulators for practical skill development in information search, analysis, and evaluation. While 50% of respondents demonstrated confident use of these tools, the majority either lacked proficiency or used them only occasionally.

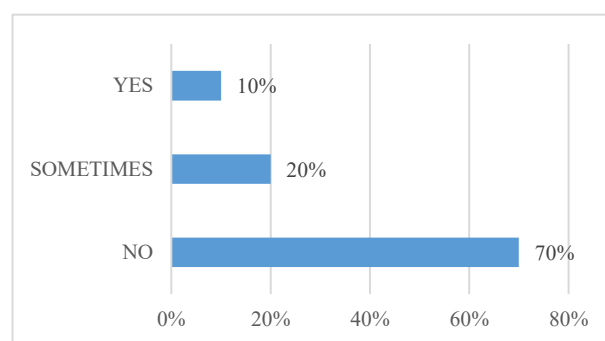


Fig.2. Modeling real-life situations.

Significant gaps were identified in students' knowledge regarding the method of modeling real-life work situations within media education, despite studying the relevant discipline for one semester.

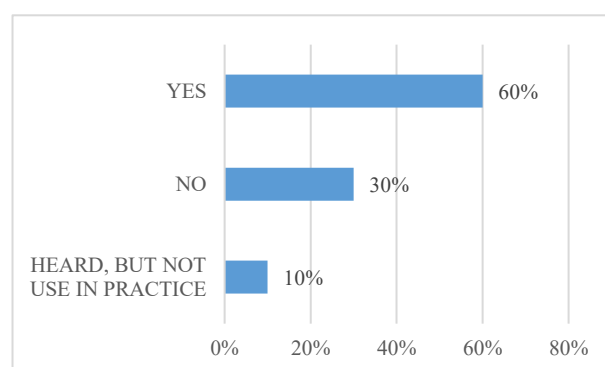


Fig.3. Collaborative learning in groups.

The survey results reveal an ambiguous attitude among students toward collaborative learning, which includes group work on studying information resources,

discussing media trends, and organizing interdisciplinary seminars. 60% of respondents expressed a positive attitude toward this method, while 30% evaluated it negatively, and 10% had no prior experience with it.

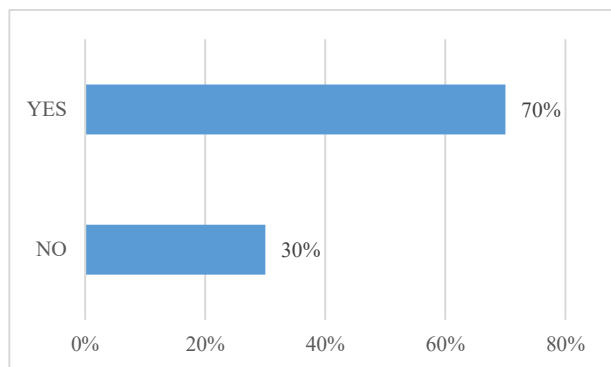


Fig.4. Interactive method.

The interactive method for developing media literacy proved to be the most popular among students in the library sciences field, as it is the most commonly practiced approach in establishing interactions between students and instructors.

The survey analysis revealed that 50% of students possess basic skills in critical media content analysis, whereas this figure is 70% among working professionals. However, only 45% of respondents reported regularly applying their acquired knowledge in practice. Various teaching methods, such as project-based learning, collaborative learning, and workplace scenario modeling, have demonstrated their effectiveness. In particular, the use of digital technologies enabled 60% of experiment participants to enhance their skills in information analysis and media content handling. Interactive sessions showed a high level of engagement, increasing students' interest in media literacy by 40%.

The research findings confirm the necessity of further developing media education among library professionals. Despite a high level of awareness regarding the importance of media literacy, the practical application of these skills remains insufficient. This highlights the need for more interactive educational programs focused on applying acquired knowledge in real professional settings.

The international experience of developed countries such as the United States, the United Kingdom, and Australia demonstrates that the key strategies for enhancing media competence among librarians include the integration of digital technologies, the development of professional communities, and continuous self-education. An analysis of international practices shows that the most successful educational programs incorporate project-based learning, digital data visualization, and the simulation of real-work scenarios.

The study revealed a direct correlation between the level of media literacy among library specialists and the quality of library services provided. This confirms the

need to integrate media literacy as an essential part of librarians' professional training.

Thus, the methods and strategies for media literacy education proposed in the study contribute to the development of essential competencies among library specialists, enabling them to work effectively in the modern information environment. Future research may focus on the development of more detailed educational programs and the study of the long-term impact of media education on librarians' professional activities.

CONCLUSION

In today's information society, where libraries are evolving from knowledge repositories into media education centers, the media competence of library specialists has become critically important. To effectively fulfill their role as information intermediaries, librarians must not only possess a broad range of skills outlined in information literacy frameworks but also continuously develop their media competencies. This requires a comprehensive approach to training that includes interactive methods, project-based learning, mastering digital technologies, and conducting research. Strategies for enhancing media literacy should involve the creation of professional communities, the integration of digital technologies, ongoing self-education, and the development of practical skills. Only through these measures can librarians effectively carry out their educational mission and contribute to the formation of a media-literate society, which is particularly relevant for Uzbekistan.

Based on the identified methods for developing media literacy, the following interrelated strategies are being developed for Uzbekistan:

1. Establishing professional communities for knowledge and experience sharing; integrating digital technologies into the educational process to enhance learning effectiveness.
2. Continuous research and self-education to maintain up-to-date competencies; developing practical skills through project-based learning and real-world scenario modeling.
3. Collaboration with external partners, including the media industry and educational institutions; systematically analyzing and evaluating professional activities to optimize approaches and achieve the best results.
4. Educational programs and courses:
 - Regular training sessions and seminars: Organizing educational events on media literacy topics such as combating fake news, analyzing media content, and social media promotion.
 - Incorporating media literacy into professional development programs: Developing media education modules within training programs for librarians.

- Online courses: Utilizing distance learning formats, including webinars, video lectures, and online platforms for self-paced study.

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ChatGPT in Educational and Scientific Activities of Grinchenko University: a Diagnostic Section

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Abstract— The article describes the state of regulation of artificial intelligence technologies development in the world and Ukraine, highlights the features of the use of AI, in particular large language models such as ChatGPT chatbot in the educational sector, including in higher education institutions, analyses a number of documents that contain recommendations for the use of artificial intelligence technologies in teaching, learning and research. The analysis has been carried out and the results of the research have been summarized by surveying students, lecturers and researchers of Borys Grinchenko Kyiv Metropolitan University regarding the problem and ways of using the digital technology of artificial intelligence chatbot ChatGPT when writing academic texts. The state of use of the specified technology in the educational and scientific activities of Borys Grinchenko Kyiv Metropolitan University has been determined, in particular, the number of respondents who are familiar with the chatbot and technologies that recognize its use in the text, and those who use them when writing academic texts, the frequency of such requests; the opinion of the interviewees has been recorded regarding the fair and ethical use of this technology and the need to indicate this fact in academic texts; the attitude of the survey participants to the need for state regulation of the use of ChatGPT in scientific and educational activities of higher education institutions, as well as normative regulation at Borys Grinchenko Kyiv Metropolitan University, has been clarified; the main risks and challenges of using this artificial intelligence technology in the educational and scientific activities of the higher education institution expressed by the respondents have been summarized; the need to hold events at Grinchenko University regarding familiarization with the

digital technology of artificial intelligence of ChatGPT chatbot, the risks and challenges arising from its use in educational and research activities have been determined. A model of using artificial intelligence technologies, in particular ChatGPT chatbot in educational and scientific activities of Grinchenko University, has been proposed and relevant recommendations have been developed.

Keywords— *Artificial intelligence technologies; ChatGPT chatbot; academic texts.*

I. INTRODUCTION

The development of scientific and technological activities, development of research and innovation infrastructure and preservation of scientific potential in Ukraine are taking place in line with European integration processes, as follows:

- the Roadmap for integration into the European Research Area has been approved;
- Ukraine has joined the STIP Compass program of the Organization for Economic Cooperation and Development and the European Commission for Science and Innovation;
- the Agreement on Ukraine's participation in the EU programs “Horizon Europe” and “Euratom” has been ratified;
- Ukraine has become the 39th full member of the COST Association for Financing of Innovation and Research Networks;

Online ISSN 2256-070X

<https://doi.org/10.17770/etr2025vol3.8514>

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- the national plan for open science has been approved;

- the possibilities of using electronic resources of scientific information by Ukrainian educational and research institutions have been significantly expanded [1].

Common scientific and educational space, communication, open access, operational exchange of research data, educational resources, etc. are coming to the forefront in the development of modern science and education. Artificial intelligence technologies play a significant role in this regard, as they help to optimize and accelerate these processes. Therefore, the issue of building a digital environment using artificial intelligence technologies is becoming increasingly relevant for the development of science and education in Ukraine.

Problem statement. Artificial intelligence technologies are becoming increasingly widespread in domestic science, education, and business. In this regard, the issue of the correct use of these technologies in the Ukrainian educational and scientific space in compliance with the principles of academic ethics and integrity is becoming more acute. In particular, we are talking about the use of digital artificial intelligence technology - ChatGPT chatbot, which has recently rapidly burst into many areas of activity of scientists and educators. Our article will analyse the state of use of this technology in the educational and scientific process of Grinchenko University.

Analysis of recent research and publications. Many countries around the world are implementing national strategies for the development of artificial intelligence, and among the first to do so are: Canada (The Pan-Canadian Artificial Intelligence Strategy, 2017), Great Britain (Digital Strategy, 2017), China (A Next Generation Artificial Intelligence Development Plan, 2017), Italy (Artificial Intelligence: At The Service of Citizens, 2018), Sweden (Nationell inriktning för artificiell intelligens, 2018), India (National Strategy for Artificial Intelligence #AIForAll, 2018), Singapore (National AI Strategy 2.0, 2023), UAE (UAE Strategy for Artificial Intelligence 2031, 2018), USA (National Artificial Intelligence Strategy, 2019), South Korea (National Strategy for Artificial Intelligence: Toward AI World Leader beyond IT, 2019), Denmark (National Strategy for Artificial Intelligence, 2019), Germany (Strategie Künstliche Intelligenz der Bundesregierung, 2020), France (Stratégie Nationale Pour L'intelligence Artificielle – 2e phase, 2021), Austria (Strategie der Bundesregierung für Künstliche Intelligenz, 2021), Japan (AI Strategy 2022) and others.

The intensive development of artificial intelligence technologies has led to the need for their legal regulation both at the state level and at the level of individual institutions. Currently, a number of documents have been developed that provide recommendations for the use of AI in various areas of human activity. Among such documents is the OECD «Council Recommendation on Artificial Intelligence», 2023 [2], European Commission

«White Paper on Artificial Intelligence: a European approach to excellence and trust» (2020 p.) [3], UNESCO «Ethics of Artificial Intelligence», 2022 [4], European Parliament «Report on intellectual property rights for the development of artificial intelligence technologies», 2020 [5] and «European Parliament resolution of 20 January 2021 on artificial intelligence: questions of interpretation and application of international law in so far as the EU is affected in the areas of civil and military uses and of state authority outside the scope of criminal justice», 2021)) [6] and others.

The European Commission has evolved in its search for approaches to regulating the use of AI technologies, starting with recommendations («Ethics Guidelines for Trustworthy Artificial Intelligence», 2019) [7]; «Policy and investment recommendations for trustworthy artificial intelligence», 2019 [8]) and moving to a legislative approach. Thus, in 2021, the AI Law was introduced (Proposal for a Regulation of the European Parliament and of the Council Laying down Harmonized Rules on Artificial Intelligence (Artificial Intelligence Act) and Amending Certain Union Legislative Acts, European Commission, 2021) [9]. On December 9, 2023, the European Parliament reached a preliminary agreement with the Council of the European Union on the Artificial Intelligence Act. This regulation aims to ensure that fundamental rights, democracy, the rule of law and environmental sustainability are protected from high-risk artificial intelligence, while stimulating innovation and making Europe a leader in this field. The rules establish obligations on AI based on its potential risks and level of impact. On March 13, 2024, the agreed text was officially adopted by the Parliament. The law entered into force on August 1, 2024 [10].

Ukraine is also concerned with the problem of developing artificial intelligence technologies and regulating its use. In particular, the National Strategy for the Development of Artificial Intelligence in Ukraine 2021-2030 [11] has been developed, which at the national level defines the priority areas of fundamental, applied and experimental research, tasks and measures for the implementation of domestic and world artificial intelligence technologies in the interests of national security and defence, economic and social development of Ukraine.

The Law of Ukraine «On Copyright and Related Rights» [12] was supplemented by Article 33 on special property rights to non-original objects generated by a computer program.

Awareness of the risks and challenges that accompany the development of artificial intelligence technologies prompted 28 countries, including the United States, the European Union, China, the United Kingdom, including Ukraine, to sign the Bletchley Declaration on Artificial Intelligence Security on the first day of the Technology Security Summit [13] organized by the British government in November 2023. This is the first agreement in the world

that establishes a common understanding of the opportunities and risks posed by borderline artificial intelligence, as well as the need for governments to work together to address the most significant issues.

Undoubtedly, the rapid development of artificial intelligence technologies cannot but affect the educational policy of higher education institutions in the world. Thus, in 2021, UNESCO prepared the document “AI and education: guidance for policy makers” [14], which offers recommendations for policy makers on the opportunities and overcoming the risks that arise when using artificial intelligence technologies in education. The document states that artificial intelligence has the potential to solve some of the biggest challenges in education today, implement innovative teaching and learning practices, and ultimately help accelerate progress towards Sustainable Development Goal 4, Quality of Education.

The world's leading universities are also developing their own approaches to the use of AI in the educational and scientific process of training future specialists. Among them are:

- Policy on the Use of AI Text Generation (Boston University, 2023 p.) [15];
- Artificial Intelligence Tools at the Hertie School Teaching Guidelines for Faculty and Students (Hertie School 2023) [16];
- Policy and practice guidance around acceptable and responsible use of AI technologies (Monash University, 2023 p.) [17];
- Guidance on AI/ChatGPT (Princeton University, 2023 p.) [18];
- Generative AI Policy Guidance (Stanford University 2023 p.) [19];
- Guidance for students on the use of Generative AI (such as ChatGPT) (The University of Edinburgh 2023 p.) [20];
- ChatGPT and Generative AI in the Classroom (University of Toronto 2023) [21] and others.

These documents, including recommendations, manuals, etc., reflect the policies of higher education institutions on the use of artificial intelligence technologies in the educational and research activities of students and lecturers. The documents have in common the realization that artificial intelligence is rapidly developing and spreading, including in the university environment, so it is necessary to use it reasonably, effectively and honestly, not to prohibit it, and to be aware of the challenges and risks associated with it. This also affects the process of evaluating students' work, developing evaluation criteria and formulating tasks that should develop critical thinking, creativity, research skills, etc.

Recommendations for the use of artificial intelligence in learning, teaching and research are also being developed by companies that provide plagiarism prevention services [22].

In our opinion, the initiative of the California State University system (CSU) together with leading global

companies (Adobe, Alphabet (Google), AWS, IBM, Instructure, Intel, LinkedIn, Microsoft, NVIDIA, OpenAI), announced in early February 2025, regarding the widespread introduction of artificial intelligence technologies into the educational process of 23 campuses of the system, which currently has no analogues in the global educational space, is progressive. Under this initiative, more than 460,000 students and 63,000 CSU employees will have free, equal and inclusive access to advanced technologies, including ChatGPT Edu, a version of ChatGPT that offers enhanced educational tools, higher security (data protection and privacy features) and management control for educational institutions to improve learning and teaching efficiency, optimize administration and timing, etc. To implement the initiative, the CSU has created a special platform (AI Commons Hub), which contains AI tools and instructions for students and employees on how to use them, curricula, certificates, etc. To develop the professional competence of CSU teachers, trainings on artificial intelligence have been offered [23].

At the same time, the widespread adoption of artificial intelligence technologies, in addition to its benefits, also carries risks associated with ethical issues such as threats to human rights, racial and gender discrimination, the impact of AI on decision-making, employment, the labour market, human interaction in society, access to information, digital inequality, security, protection and confidentiality of personal data, copyright, data analysis and manipulation, AI as a source of bias based on gender, ethnicity, age, etc. This is stated in such documents as ‘AI and education: guidance for policy-makers’ [14], ‘Recommendation on the Ethics of Artificial Intelligence’ [24] and ‘UNESCO's Recommendation on the Ethics of Artificial Intelligence: key facts’ [25]. There are also still unresolved issues related to the impact of artificial intelligence technologies on the development of intelligence and critical thinking, research skills, the level of education and competence of students, dependence on these technologies, etc.

Ukrainian universities are also creating recommendations on the use of AI in the training of higher education students. In particular, Kherson State University has developed a document called “General Policy on the Use of Artificial Intelligence in Learning, Teaching and Research at Kherson State University” [26]. This document regulates the main directions, ways and means of effective use of information technologies related to artificial intelligence for participants in the educational process in learning, teaching, research and publication activities. In particular, it proposes specific AI technologies, provides instructions on how to interact with these technologies, outlines the possibilities and methods of their application in the listed activities, and regulates those activities where it is not desirable to use these technologies. In our opinion, this document does not fully cover the aspects related to ethics and compliance with the

principles of academic integrity in the use of artificial intelligence technologies.

As noted in the works of O. Hrytsenchuk, the concept of artificial intelligence technology is the ability of digital technologies to perform tasks for which a person uses his or her intelligence [27].

In turn, M. Marienko and V. Kovalenko claim in their works that artificial intelligence technology and open science in education is the use of technology and cloud services of open science, which significantly diversifies and improves the visualization of materials and is based on a methodological component [28].

Having analysed the use of AI in the context of Bloom's taxonomy [29], which consists of six main levels (knowledge, understanding, application, analysis, evaluation and synthesis), we observe the feasibility of its implementation in the educational process:

- Knowledge: AI technology allows effectively memorise information by personalising content for a specific participant in the educational process and provides an opportunity to develop tests that help improve memory and information retrieval (Quizlet application);

- Understanding: AI technology allows to: understand complex concepts of the educational process, explaining them in different ways and adapting them to the individual needs of the educational process participant; create chatbots or virtual assistants that can explain/answer questions (Siri or Google Assistant applications);

- Application: AI technology makes it possible to apply knowledge in the educational process in real conditions through simulations of real scientific processes/curricula (virtual laboratories);

- Analysis: AI technology promotes the development of critical thinking and analysis skills in the educational process, helping to break down complex problems into simpler components (analysis of large data sets);

- Evaluation: AI technology allows to assess challenges in the educational process and provides objective and efficient assessment for process automation (argumentation and logical sequence of the educational process);

- Synthesis: AI technology allows to stimulate creative thinking in the educational process by synthesising new ideas or solutions from the knowledge gained (automated content creation systems, audio generation).

Consideration of AI technology in the context of the SAMR model (The Substitution Augmentation Modification Redefinition Model) [30] in combination with the above-mentioned Bloom's taxonomy makes it possible to assess the degree of positive impact of AI on the educational process. The SAMR model defines the following stages: innovations in the implementation of AI technology to perform traditional tasks in the educational process (levels of 'substitution' and 'improvement'); fundamental transformations of the educational process (levels of 'modification' and 'transformation'). In

addition, it allows to identify the purpose and results of the integration of AI technology.

- Substitution: AI technology acts as an optimiser, replacing the existing traditional tools in the educational process with the digital technology of today. This makes it possible to reduce the processing time of relevant requests in the educational process.

- Improvement: AI technology improves the efficiency of each participant in the educational process by personalising content for each individual.

- Modification: AI technology is changing the way we perform tasks, creating new forms of interaction (interactive and practical) in the educational process.

- Transformation: AI technology creates new methods of work in the educational process that were previously impossible.

Therefore, in view the above, we can state that AI technology helps to optimise and improve the processes of memorising, understanding, applying, analysing, evaluating and synthesising knowledge, which in turn optimises, enhances, modifies and creates new methods of work in the educational process.

Among the artificial intelligence technologies that can have a significant impact on higher education, scientists call generative technologies - large language models, such as ChatGPT chatbot [31]. ChatGPT is a generative technology developed by OpenAI, an American company engaged in the research and implementation of artificial intelligence. Generative artificial intelligence generates new results based on the data it has been trained on and uses deep learning to create completely new content [32].

According to scientists, these and similar generative models for producing and processing text, images, audio, video, etc. can change the educational landscape in the training of future professionals, transform approaches, principles of form and methods of learning and teaching in higher education institutions [31, p.3].

Given the rapid spread of ChatGPT chatbot in many areas of human activity, including the educational process of higher education institutions, international organizations are developing recommendations and guidelines for using this technology. Among them are the UNESCO manual "ChatGPT and Artificial Intelligence in higher education: Quick start guide" [4], the manual "Unlocking the Power of Generative AI Models and Systems such as GPT-4 and ChatGPT for Higher Education: A Guide for Students and Lecturers" [34], Guide with ChatGPT Prompts for Teachers [33], etc. [34].

The research purpose. To identify the state, risks and challenges of using digital artificial intelligence technology ChatGPT chatbot in writing academic texts by academic staff and students of Grinchenko University and to develop a model for the use of artificial intelligence technologies, in particular ChatGPT chatbot in educational and scientific activities and provide relevant recommendations.

II. MATERIALS AND METHODS

In 2024, in order to clarify the need for rationing the use of ChatGPT chatbot in educational and scientific activities, the research was conducted at Borys Grinchenko Kyiv Metropolitan University on the problem and methods of using this digital artificial intelligence technology when writing academic texts by academic staff and students.

The research was conducted by means of a survey (Google Workspace service) on predefined questions among students of all levels, lecturers and researchers of the University. The survey results for each question are presented in the form of graphs, diagrams and tables. During the survey, a number of questions were asked regarding the use of digital artificial intelligence technology ChatGPT chatbot in writing academic texts.

1801 respondents provided the answers, including: 336 college students, 723 bachelor's students, 124 master's students, 54 PhD students, 525 lecturers and 39 researchers.

To the question "Are you familiar with the digital artificial intelligence technology ChatGPT?" 52% of the total number of respondents answered "Yes," 31% - "Partially," and 17% - "No" "Fig. 1".

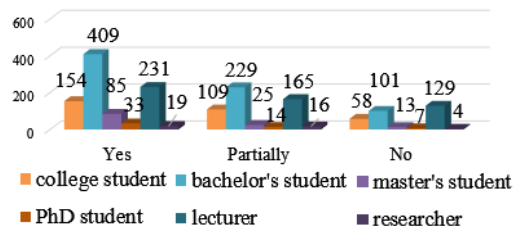


Fig. 1. Respondents' answers.

The analysis of the responses indicates a generally high percentage of familiarity of the surveyed students, lecturers and researchers of the University with the digital artificial intelligence technology ChatGPT. This is also undoubtedly evidence of the rapid development and rapid spread of artificial intelligence technologies, in particular ChatGPT chatbot, which has gained wide popularity in the academic environment in a short period of time.

The following answers were received to the question "Have you used the digital artificial intelligence technology ChatGPT chatbot when writing academic texts?": 76% of all respondents answered "No," 21% - "Partially," and 3% - "Yes" "Fig. 2".

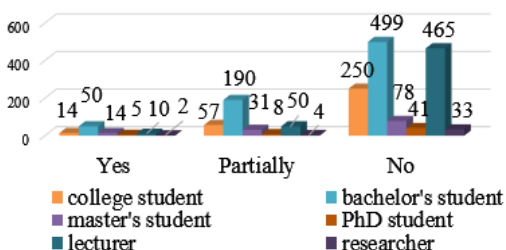


Fig. 2. Respondents' answers.

In general, the analysis of responses shows a low percentage of students, lecturers and researchers using the digital artificial intelligence technology ChatGPT chatbot when writing academic texts.

The respondents answered the question "How do you use the digital artificial intelligence technology ChatGPT chatbot when writing academic texts?" as follows "Fig. 3":

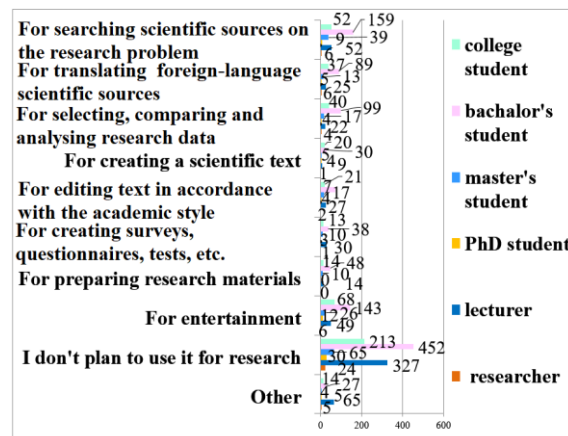


Fig. 3. Respondents' answers.

Having summarized the responses by categories "college student," "bachelor's student," "master's student," "PhD student," "lecturer," and "researcher," we have the following results:

college students indicated that they use chatbots when writing academic texts to search for scientific sources on the research problem (11%), select, compare and analyse research data (8%), translate foreign language scientific sources (7%), create a scientific text (4%), edit the text in accordance with the academic style (4%), create surveys, questionnaires, tests, etc. (3%), and design research materials (3%). 43% of respondents do not plan to use ChatGPT for academic work, 14% use the chatbot for entertainment and 3% use it for other purposes, including finding creative ideas for practice, creating tests and presentations, and pursuing personal purposes not related to education and research;

bachelor's students responded that they used chatbot to search for scientific sources on the research problem (14%), translate foreign-language scientific sources (8%), select, compare and analyse research data (9%), create a scientific text (3%), edit the text in accordance with the academic style (6%), design research materials (4%), create surveys, questionnaires, tests, etc. (3%). 39% of respondents do not plan to use chatbot for research, 12% use it for entertainment, and 2% use it for other purposes, such as searching for information, preparing for seminars and practical assignments, essays, etc;

for *master's students*, the chatbot was useful for searching scientific sources on the research problem (19%), selecting, comparing and analysing research data (8%), editing text in accordance with the academic style (8%), translating foreign language scientific sources (6%), creating surveys, questionnaires, tests, etc. (5%),

designing research materials (5%), creating a scientific text (2%). 32% of applicants do not plan to use the chatbot for research, 13% communicate with ChatGPT for entertainment, and 2% use the chatbot for personal needs;

PhD students used the chatbot to search for scientific sources on the research problem (12%), translate foreign-language scientific sources (7%), select, compare and analyse research data (5%), create a scientific text (5%), edit the text in accordance with the academic style (5%), create surveys, questionnaires, tests, etc. (4%), design research materials (0%). 39% of respondents do not plan to use the chatbot for research, 16% use it for entertainment and 7% find other use, such as preparing presentations, creating lists of references, etc;

lecturers used ChatGPT to search for scientific sources on the research problem (11%), translate foreign-language scientific sources (11%), select, compare and analyse research data (7%), edit text in accordance with the academic style (4%), create a scientific text (2%), create surveys, questionnaires, tests, etc. (2%), design research materials (0%). 53% of the respondents do not plan to use the technology for research, 11% use it for entertainment, 11% provided answers regarding the use of the chatbot in the “Other” category, in particular, it was useful for preparing lectures and practical classes, searching for sources and checking student papers, etc.;

researchers used the chatbot to search for scientific sources on the research problem (11%), translate foreign language scientific sources (0%), select, compare and analyse research data (5%), create a scientific text (0%), edit text in accordance with the academic style (0%), create surveys, questionnaires, tests, etc. (0%), design research materials (0%). 43% of respondents do not plan to use the chatbot for research, 16% use it for entertainment, 9% use it for other activities, such as comparing information with search queries on the Internet, checking written papers for plagiarism, or usage of artificial intelligence.

Analysis of the responses shows that 42% of respondents in all these categories chose the answer “I do not plan to use it for research.” 37% of respondents use ChatGPT to optimize and speed up the processing of information and sources when writing academic texts, designing materials, working, conducting empirical research, etc. 19% use the chatbot for entertainment. Only 2% used the chatbot to create a scientific text. Such results demonstrate a sufficiently high level of formation of academic integrity culture among students and employees of Grinchenko University.

To the question “*In your opinion, can the use of digital artificial intelligence technology ChatGPT chatbot violate the principles of academic integrity?*” 30% of respondents answered “Yes,” 43% - “Partially,” and 27% - “No” “Fig. 4”.

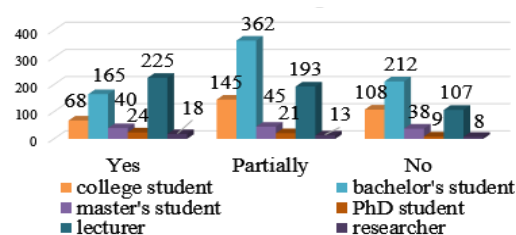


Fig. 4. Respondents' answers.

Analysis of the responses shows that the majority of respondents believe that the use of digital artificial intelligence technology ChatGPT chatbot violates the principles of academic integrity.

In the survey, to the question “*Do you indicate the use of artificial intelligence technologies in the materials and/or methods of academic texts?*” 2% of respondents answered “Yes”, 12% - “Partially”, 86% - “No” (did not use ChatGPT) “Fig. 5”.

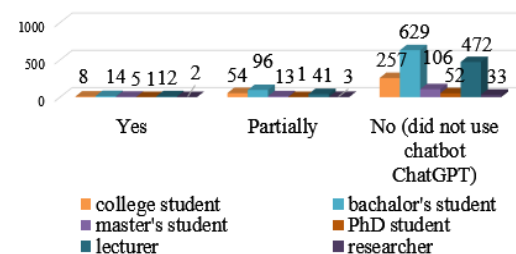


Fig. 5. Respondents' answers.

Analysis of the responses showed that respondents mention the use of artificial intelligence technologies in the materials and/or methods of academic texts. However, the percentage of such users is low, as most respondents do not use artificial intelligence technology for their educational and research activities. Doubts and conflicting opinions of respondents on this issue prompt the preparation of a document on the use of artificial intelligence technologies in educational and scientific activities and a series of trainings and workshops on mastering the basics of their use.

To the question “*In your opinion, does the use of digital artificial intelligence technology ChatGPT require state regulation in scientific and educational activities of higher education institutions?*” 33% of respondents answered “Yes,” 30% - “Partially,” and 37% - “No” “Fig. 6”.

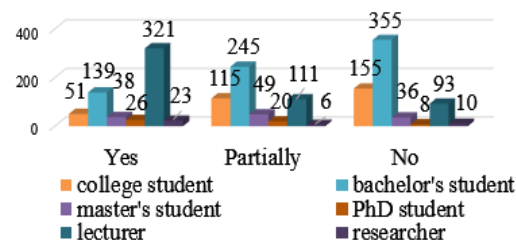


Fig. 6. Respondents' answers.

Analysis of the responses shows that, according to the respondents, the use of digital artificial intelligence

technology ChatGPT requires state regulation in the scientific and educational activities of higher education institutions. This opinion is shared by the majority of PhD students, lecturers and researchers, as they realize the complexity and urgent need to resolve this issue. However, it should be noted that almost half of the respondents in the categories “college students” (48%) and “bachelor's students” (48%) indicated that “it does not require”. This position may be explained by insufficient awareness of this technology, ignorance of state legal norms and mechanisms, misunderstanding of the connection between the use of chatbot and compliance with the principles of academic integrity, copyright, etc.

To the question “*In your opinion, does the use of digital artificial intelligence technology ChatGPT require normative regulation at Grinchenko University?*” 31% of respondents answered “Yes,” 29% - “Partially,” and 40% - “No” (Fig. 7).

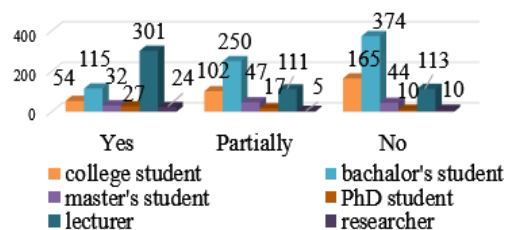


Fig. 7. Respondents' answers.

Analysis of the answers showed that, in the respondents' opinion, the use of digital artificial intelligence technology ChatGPT requires normative regulation at Grinchenko University. As in the answers to the previous question, most PhD students, lecturers and researchers consider such regulation relevant and desirable.

And a significant number of respondents in the categories “college students” (51%), “bachelor's students” (51%), “master's students” (36%) indicated “it does not require”. The answers to this question from these categories correlate with the answers to the previous question and confirm our assumption about the reasons for this reaction.

To the question “*Please describe how the use of digital artificial intelligence technology ChatGPT should be regulated at Grinchenko University,*” the respondents gave the following answers:

23% of *college students* noted that there is no need to regulate the use of the chatbot at Grinchenko University, the reason for this decision is the following: it is convenient for searching information, the same information as from the Internet, it is impossible to regulate, provides inaccurate data, etc. 21% of respondents believe that it is necessary to conduct explanatory and educational work in the form of conversations, lectures, workshops, trainings, etc. among students to familiarize them with the positive and negative aspects of using ChatGPT. 16% - emphasize that in order to prevent violations of the principles of academic integrity, it is

necessary to check all types of educational and scientific activities of students with services that recognize the use of artificial intelligence, including ChatGPT in academic texts. 14% - suggest allowing the chatbot, provided that the purpose of the work, the fact of its use and the limits of its use are specified in the work. 14% - cannot answer this question because they feel insufficiently competent in this area. 6% of respondents recommend developing rules for using the chatbot or amending the Regulation on academic integrity of scientific-pedagogical, research, teaching staff and students of Borys Grinchenko Kyiv Metropolitan University. 6% - put forward a proposal to prohibit or restrict the use of ChatGPT in the educational and scientific process of the University. 2% of applicants provided answers that do not relate to the specified problem.

27% of *bachelor's students* believe that Grinchenko University should regulate the use of the digital technology of artificial intelligence chatbot ChatGPT, through clear policies and ethical standards by: providing appropriate training and supervision by faculty and administration to ensure that the chatbot is used in accordance with the University's standards; defining specific areas of application of the chatbot in the educational and scientific process; providing students with the necessary support for the correct use of the chatbot and avoiding its misuse; developing or supplementing existing regulatory documents, publicly disclosing ethical principles that regulate the use of artificial intelligence in the university environment; ensuring openness in the use of the chatbot, including its capabilities and limitations, for all stakeholders, including students, teachers and the public; there were also proposals to improve the tasks themselves (they should be creative), revise the criteria for evaluating student work, establish reasonable volumes of processing the given material, etc. 19% of respondents did not answer this question due to lack of awareness, fear of the complexity of this problem, “because I am a philologist, not a computer scientist.” 17% insist that there is no need to regulate this process, since its prohibition or restriction will cause a backlash from potential users, and permission is not needed because everyone uses chatbots anyway. 16% suggest that materials created with the help of a chatbot should be subjected to verification through relevant services or by teachers who, through oral questioning or other forms of control, can detect the fact of ChatGPT use. 10% recommend organizing various events to educate and understand the ethical implications of using artificial intelligence technologies. According to 9% of respondents, it is necessary to ban or restrict the use of the chatbot in research, qualification and dissertation works, given the threat to the development of intellectual and creative abilities of the individual, the uniqueness of research and academic integrity at the University. 2% in their responses shifted the responsibility for solving this problem to the administration and emphasized that this is

not an urgent problem at the moment, noted that teachers should make sure that students do not use the chatbot, etc.

48% of *master's students* answered that this issue should be regulated at the University level by developing standards, norms, rules, guidelines for using ChatGPT chatbot to prevent violations of academic integrity, through the system of internal quality assurance of education, at the level of developing curricula for academic disciplines in the formulation of search-heuristic and creative tasks in the optimal amount for students, which encourage independence in solving these tasks, etc. 15% of respondents noted that the use of this technology does not require regulation at the University. 11% believe that to resolve this problem, it is necessary to check academic texts for the presence of the text generated by the chatbot using special software, moreover, to develop a special application for this purpose. 9% of applicants suggest holding certain events and developing training modules for mastering the skills of using ChatGPT. According to 5% of respondents, it is necessary to prohibit or limit the use of this technology in the activities of applicants and scientists by developing an appropriate document.

57% of PhD students noted that to resolve this issue, it is necessary to develop a policy for the use of artificial intelligence technologies at the University level, guidelines for their ethical use, methodological recommendations and control mechanisms for their application, and to supplement the Regulation on academic integrity with relevant points. Some respondents believe that the problem cannot be solved at the level of a higher education institution by delegating such powers to state bodies, in particular the Ministry of Education and Science of Ukraine. 18% – are not ready to answer this question. 14% – believe that it is necessary to strengthen the mechanisms for checking academic texts for the presence of chatbot-generated content, to introduce additional checks in addition to the usual plagiarism checks. According to 7% of respondents, there is no need to regulate this issue at the University level. 2% – recommend limiting the use of ChatGPT. 2% – suggest familiarizing participants in the educational process with artificial intelligence technologies.

43% of teachers believe that regulating the use of the chatbot in educational and scientific activities of participants in the educational process at the University level involves the creation of an appropriate regulation, recommendations, instructions, a code of ethics, the establishment of clear rules for its application, improving the content of existing regulatory documents on academic integrity, the educational process, etc., among them 4% emphasize that this issue should first be regulated at the state level (MES, legal state bodies, IT sphere, etc.), and then implemented in the work of the University. 25% of respondents cannot answer due to lack of awareness of this technology, emphasizing that this issue should be resolved by the vice-rector for research or other responsible

persons, etc. 10% are convinced that all the work of students and teachers should be subject to various forms of control and be checked by specialized tools to detect ChatGPT-generated text. 8% of respondents propose to prohibit chatbots completely or only when writing qualification and dissertation papers, research papers, semester and final control tasks, as well as to restrict access to it completely or partially. 7% feel the need to learn how to use the chatbot correctly to avoid problems with violations of academic integrity, etc. 6% of the teaching staff noted that there is no need to regulate this issue at the University level, as it is impossible, restricts personal freedom, does not comply with “new digital laws adopted by 2019,” does not make sense, etc. 1% did not provide clear and adequate answers to the questionnaire.

38% of researchers responded that in order to resolve the issue of regulating the use of the chatbot at the University level, it is necessary to create appropriate documents, regulate the use of certain types of works and supplement the existing Regulation on academic integrity of scientific-pedagogical, research, teaching staff of Borys Grinchenko Kyiv Metropolitan University. According to 18% of respondents, it is necessary to check works for the presence of the text produced by the chatbot, to put an automatic marking that will be indicated when copying the text from the chat and which will not be possible to delete. 13% believe that there is no need to regulate the use of ChatGPT, since there are more pressing issues and tasks at the moment. 13% suggest discussing this issue through conducting a survey. 6% of respondents do not know the answer to the question because they do not feel competent enough to do so. 6% said that it is necessary to conduct explanatory work on the consequences of using this technology in academic texts. 6% are in favour of banning the chatbot.

To the question “*Is it necessary to hold events at the University to familiarize with the digital technology of artificial intelligence ChatGPT, the risks and challenges that arise when using it in research activities?*” 59% of respondents answered “Yes”, 22% - “Partially”, 19% - “No” “Fig. 8”.

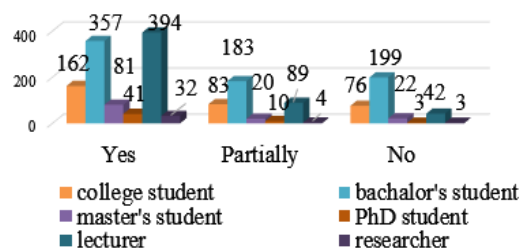


Fig. 8. Respondents' answers.

Analysis of the answers showed that most respondents need to familiarize themselves with the digital artificial intelligence technology of ChatGPT chatbot, the risks and challenges that arise when using it in research activities.

III. RESULTS AND DISCUSSION

The results of the survey prompted us to develop a model for the use of artificial intelligence technologies, in particular ChatGPT chatbot, in the educational and research activities of Grinchenko University "Fig. 9", which will serve as a basis for:

- taking into account the functionality of ChatGPT when preparing educational material for its quality assimilation by students (different levels);
- ensuring the possibility of applying the acquired theoretical knowledge, practical skills and abilities by students (different levels) to solve certain intellectual tasks and work with intellectual systems in educational and scientific activities;
- studying and developing the regulatory framework of Grinchenko University to standardize and regulate the use of ChatGPT in the scientific and educational activities of participants in the educational process;
- using ChatGPT when teaching academic subjects to students (various levels);
- improving ethical and digital competencies of participants in the educational process;
- developing and implementing advanced training programs for scientific-pedagogical, research and teaching staff on the implementation and proper use of ChatGPT in educational and scientific activities.

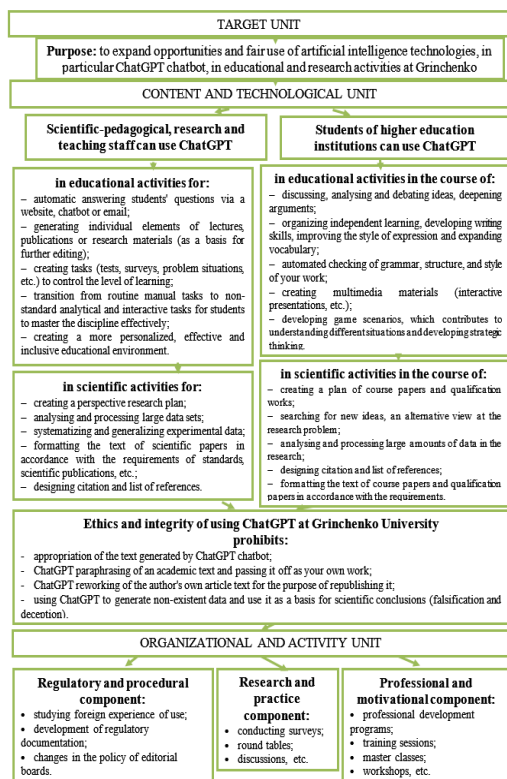


Fig. 9. Model of using artificial intelligence technologies, in particular ChatGPT chatbot, in educational and scientific activities at Grinchenko University

To implement this model in the educational and scientific activities of Grinchenko University, we offer the following recommendations:

- to update the text of the Regulation on academic integrity of scientific-pedagogical, research, teaching staff and students of Borys Grinchenko Kyiv Metropolitan University in Part 2. Compliance with the principles of academic integrity and Part 4. Violation of the requirements of academic integrity;
- to supplement the editorial policies of the University's scientific publications with a section "Policy on AI support tools", where it is noted that Large Language Models (LLMs), such as ChatGPT from OpenAI, do not qualify for authorship status. The use of LLMs in the study should be properly documented in the "Methods" section or in an appropriate alternative section if the "Methods" section is not available;
- to amend the Requirements for preparation and defense of qualification theses of students of the first (bachelor's) and second (master's) level of higher education in Part 4. Requirements for the design of qualification work;
- to develop a Policy for the use of artificial intelligence in various areas of the University's activities;
- in order to familiarize with artificial intelligence technologies, to supplement the Plan of scientific events on academic integrity with round tables, a series of webinars, workshops, online trainings devoted to theoretical and practical aspects of the use of artificial intelligence technologies in the scientific and educational activities of participants in the educational process, risks and challenges of its use in terms of academic integrity and intellectual property, legal grounds for its use, the impact of machine intelligence on society and humans, etc.;
- develop and conduct a series of introductory trainings for employees on "Artificial intelligence in teaching" as part of the digital module for professional development of University employees and a series of webinars on the "Fair use of artificial intelligence technologies in educational and scientific space of higher education institutions".

IV. CONCLUSIONS

The article analyses the state of regulation of development of artificial intelligence technologies in the world and Ukraine, highlights the peculiarities of using AI, in particular, large language models such as ChatGPT chatbot in the educational sector, including in higher education institutions, and analyses a number of documents containing recommendations on the use of artificial intelligence technologies in teaching, learning and research.

Based on the above survey data and summarizing the responses of college students, bachelor's, master's, PhD students, lecturers and researchers of the University, we can draw the following conclusions:

- more than half of the respondents are familiar with the artificial intelligence technology ChatGPT;
- only about a quarter of respondents use the chatbot to prepare for writing various types of academic texts, in particular, to search for scientific sources on the research problem, select, compare and analyse research data, translate foreign-language scientific sources, edit text in accordance with academic style, create surveys, questionnaires, tests, etc., design research materials, create scientific text. Some of them use ChatGPT for educational purposes and entertainment;
- use of the chatbot by higher education institution students, teachers and researchers is not systematic;
- according to the vast majority of survey participants, use of the chatbot in scientific and educational activities may violate the principles of academic integrity and copyright;
- vast majority of respondents consider it necessary to indicate in a scientific paper how the digital artificial intelligence technology ChatGPT was used, but only a small percentage of higher education institution students, lecturers and researchers note this fact in the materials and/or methods of academic texts;
- more than half of the respondents said that the use of digital artificial intelligence technology ChatGPT chatbot requires full or partial state regulation in the scientific and educational activities of higher education institutions, as well as normative regulation at Grinchenko University;
- about half of the survey participants suggest developing separate documents at the university level or supplementing the current Regulation on academic integrity of scientific- pedagogical, research, teaching staff and students of Borys Grinchenko Kyiv Metropolitan University to regulate the use of artificial intelligence technologies in the educational and scientific activities of participants in the educational process, as well as subject academic texts to verification for the presence of a chatbot product;
- about 80% of the survey participants are convinced that it is necessary to hold events at the University to familiarize them with the digital artificial intelligence technology of ChatGPT chatbot, the risks and challenges that arise when using it in research activities.

Thus, the aggregate and analysis of the respondents' answers to the questions made it possible to analyse the level and scope of the use of digital artificial intelligence technology of ChatGPT chatbot in writing academic texts. The respondents' answers showed the need to regulate the use of ChatGPT at the University and to clarify the specifics of the use of digital artificial intelligence technology of ChatGPT chatbot in writing academic texts by academic staff and students through round tables, webinars, lectures, trainings, workshops and other events to improve the development of academic integrity culture at Grinchenko University.

Based on the results of the survey, a model has been developed and recommendations have been given for the use of artificial intelligence technologies, in particular, ChatGPT chatbot in the educational and scientific activities of Grinchenko University. It is planned to develop a Policy for the use of artificial intelligence in various areas of the University's activities. When the Ministry of Education and Science of Ukraine develops recommendations for the use of AI in educational institutions, Grinchenko University will provide proposals based on the results of our research.

The next stage of our research will be to conduct the second diagnostic cross-section to test the effectiveness of the proposed model of using artificial intelligence technologies, in particular ChatGPT chatbot, in the educational and scientific activities of Grinchenko University.

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Factors Determining Students Activity in Virtual Discussion

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Abstract—Debates and discussions have long been essential in university education, yet technological advancements have transformed their preparation, organisation, and evaluation. Historically, public discourse was limited to experts or those with social status. Today, digital platforms provide this opportunity to everyone, aligning with the creative society paradigm. However, this accessibility has blurred the distinction between free expression and structured debate skills. Although freedom of speech is a democratic right, it does not guarantee the ability to engage in meaningful discussions. Therefore, it is especially important to pay attention to teaching of debates and discussions or learning through discussion and debating in universities.

Various digital platforms incorporate algorithm-based tools for learning and discussion, but they often lack effectiveness, adaptability, and popularity. Mechanised tools developed without research are not effective and do not address the needs of the target audience. Therefore, the development of any machine learning tool, algorithm or platform should start with an experiential study of the target group. This study investigates what motivates students to actively engage in virtual discussions and what platform features encourage their sustained participation.

An empirical study was conducted with 61 first-year PhD students (average age: 31). They watched three movies, formulated discussion questions, and participated in online debates via Moodle. Subsequently, they reflected on their experiences and identified key engagement factors, which were categorized into seven themes: Meaning Construction; Topic Features; Task-Related Requirements; Requirements for Virtual Discussion Platform; Virtual Discussion Activity; Nature and Structure of Communication; Social Interaction.

The findings indicate that students are more active when the discussion topics are clear, directly related to their

studies, and thought-provoking. Some students participate only due to assessment requirements, preferring in-person interactions. The study also highlights the growing issue of digital loneliness and the importance of fostering strong social connections in online learning environments. Additionally, an intuitive and visually appealing platform strengthens engagement, as students prefer tools that require minimal effort to navigate. Emotional connection with other PhD students, prompt responses from peers, and visible participant profiles further contribute to active participation.

These insights are essential for designing effective virtual learning environments. The study highlights the necessity of user-centred design, which ensures that online platforms are not only functional but also foster meaningful engagement, social interaction, and enriching learning experience.

Keywords—Student Engagement, Tools and Techniques, Virtual Discussions and Debates.

I. INTRODUCTION

Debate and discussion are among the oldest methods in university education [1] - [3]. Dialogical methods are low in material resource requirements, and therefore various forms of debate can be organised in educational institutions with limited material resources [4]. Skilful teachers have turned people's oral communication practices into a skilful form of education. The dialogical method of study requires not only communicative skills, but also creative thinking, critical thinking, intellectual expression, etc. [5] - [4]. Debate allows for the integration of different cultures, perspectives and values in the analysis of many topics from different perspectives [7] - [11]. It should be noted that there are various forms of debate and discussion, but all of them are dominated by the principle of expressing different

Online ISSN 2256-070X

<https://doi.org/10.17770/etr2025vol3.8527>

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points of view. In many cases, the ability to think critically, to articulate one's point of view, and to respond effectively to an opponent's statements is extremely important in debate. However, it is quite rare for the discussion of the debate or the explanation of the method itself to emphasise philosophical thought or the philosophical consensus, which is the fundamental basis of the debate. Different people have different views. This creates diversity and even added value. However, debate helps to make people with different points of view aware that they are in the same philosophical field, which eliminates arguments, anger and unhealthy competition [12], [13]. Although debates can take various forms and offer multiple undeniable benefits, they are classified as traditional educational methods, rooted in the logic of print and based on the notion that there is only one true view of reality. In practice, the use of the Internet disrupts this traditional educational logic. This new logic of education is dialogical and describes education as learning to learn, think and thrive with multiple perspectives and in a context of the greatest uncertainty [13], [14]. As technology advances, the preparation, organisation, and evaluation of debates are also changing. At the same time, there appear more and more opportunities to bring dialogical methods of study into the virtual space. The modernisation of traditional educational methods raises problematic questions and increases the need for research.

One problematic area of research is the shift in who can publicly express opinions. Technological advances have removed social barriers to expressing opinions and have made it possible for everyone to express their opinions in various forms: comments, social networks, reels, influencers, social networking groups, etc. This correlates with the paradigm of a creative society, which encourages even young children to have and express their opinions. And there are many communication channels for the expression of opinions [15], [16], [17]. This allows for the conflation of opinion with the ability to learn, create knowledge, discuss or debate [18], [19]. The expression of opinions is linked to the freedom to express a point of view, the freedom to hold an opinion. A democratic society encourages free expression; however, not all forms of expression constitute a debate. Expressing an opinion is not equivalent to engaging in discussion, much less in debate. The authors of the article have analysed the relationship between debate, discussion and controversy in more detail in another scientific article [20]. However, it is worth mentioning that the discussed problem field of research is intertwined with another problem field of research, i.e., opinion leadership. In this field, not only leadership, but also the problems of information reliability, sources of information, lies, dilettantism, the need for critical thinking, the ability to search for information, to recognise and interpret it, and similar problems are closely related.

Another problematic area of research concerns the organisation of discussions and debates. Debates originated from philosophical discussions in open urban spaces,

where listeners gathered freely. The leader's arrival in the town square is also his free choice of that day and of that moment. Thus, in their nature, discussion and debate have the freedom to choose to engage in these activities. Academic freedom is often seen as the absolute value of modern higher education institutions. "*Academic freedom is often regarded as an absolute value of higher education institutions*" [21]. The concept of freedom and its exploration becomes central to existential philosophical education in the works of Kierkegaard, K. Jaspers, P. Sartre, Albert Camus, M. Heidegger, J. Gierhuis, A. Maceina and others [22]. Although the philosophical texts of the latter thinkers offer different and subjective approaches to the problem of freedom, all these thinkers undoubtedly agreed that freedom is the fundamental and most important value of human life, which is closely linked to the self-creation and development of the personality, to responsibility, to the search for meaning, to the ability to understand and control oneself and to fulfil the purpose of the individual's life. Value-related issues encourage free thinking and the aspect of individual experience, which invariably increases student engagement and motivation; research shows that the "Socratic method" enhances student engagement and attendance [23]. In the age of technology, face-to-face communication has been replaced in many places by remote and virtual communication. Along with communication, debate and discussion are moving into virtual space. One of the channels for virtual debate is the university lecture. Universities are moving some of their studies to virtual space to make them more attractive. This is due to the technological competences, flexibility, etc. of lecturers. However, virtual communication has also opened up another problem area: participant activation. To maintain students' voluntary participation in virtual space, it is essential to identify and create an environment that appeals to them. This fact becomes particularly important when we are on the verge of integrating artificial intelligence into learning processes. When designing learning platforms, we need to know what kind of platform is needed for the student to choose it for the learning process. The global pandemic of COVID-19 has enabled virtual space to flourish [24], [25], [26]. And today we have a really wide variety of learning, entertainment and other platforms that already have algorithm-based tools built into them, but they are not effective, they are not popular, they are hard to use, etc. Therefore, the problem of this paper is formulated in terms of the following questions: What motivates students to actively participate in a virtual discussion? This problematic question aims to be answered by referring to the authentic experiences of students and insights based on experience. What kind of virtual platform would encourage students to stay in the virtual space as long as possible? Mechanised tools developed without research are not effective and do not address the needs of the target audience. Therefore, the development of any machine learning, algorithm or platform should start with an experiential study of the target group.

Research question: what are the factors that contribute to the activity of virtual discussion in the educational process?

The object of the study: doctoral students' opinion on the factors determining the activity of virtual discussion in the educational process.

II. MATERIALS AND METHODS

A qualitative study was conducted to disclose the determinants of students' participation in the virtual discussion. During the initial teacher training (the subject is called Academic Communication), PhD students performed the following task: they watched three films specified by the lecturer and created their own discussion questions and topics, as well as participated in the discussions raised by each other in the virtual space (Moodle). After the task was completed, the PhD students anonymously answered some questions about virtual discussions in the study process posed by the lecturer. One of the questions asked is: *Please list the factors that make a virtual discussion active.* The latter is the question analysed in this paper.

The study involved 61 first-year PhD students. The average age of the informants was 31 years, with the youngest being 25 and the oldest 51 years old. The survey was carried out in autumn 2021 and 2022.

For the data analysis, the informants' responses were grouped according to their meaning, and sub-categories were created and combined into categories. Seven categories of factors influencing virtual discussion activity were identified: Constructing Meaning; Topic Features; Task-related Requirements; Requirements for Virtual Discussion Platform; Virtual Discussion Activity; Nature and Structure of Communication; Social Interaction.

III. RESULTS AND DISCUSION

The form of the task is chosen for the implementation of the study process, the formulation of the task considers the aim and learning outcomes of the study programme, the mission of the University, the needs of the labour market and the needs expressed and identified by the students. The selection and formulation of the task is the basis for the student's activity, which contributes to preparation of a well-trained professional. Therefore, the requirements for the student performance in the task are really high. This is supported by the two categories identified during the research: Constructing Meaning (Table 1) and Task-Related Requirements (Table 2). The category of Meaning Construction is made up of five subcategories: idea; theme; object; keywords; and wording (Table 1).

TABLE 1. THE CONSTRUCT OF THE CATEGORY OF MEANING CONSTRUCTION

Category	Subcategory	Statements
Constructing Meaning	Idea	"idea" (2022D61);

Theme	"The topic of the debate determines activity" (2021D9);
Object	"Detailed description of the subject of the debate. Formulated discussion questions." (2022D44);
Keywords	"challenging keywords" (2021D11);
Wording	"and the presentation (if interestingly worded, it will automatically increase activity in the topic)" (2022D42);

The results of qualitative research show that participants need clarity and meaning to engage in a virtual discussion. A considerable number of activities start with an "idea" (2022D61) and then participants' "engagement is determined by the topic of discussion" (2021D9). The preparation for the discussion is likely to take place using virtual space. In this case, keywords are very important. Keywords facilitate information retrieval [27], help to stay on-topic with a variety of information, and eliminate the student from thinking about topic frames and the wording of information search queries. The ability of the research participants to analyse the topic is indicated by the expressed need to have a distinct object. Interestingly, the wording of the task is also important for PhD students: "a well formulated question that reflects the topic and current issues" (2021D26); "a simple and clear wording of the topic, with the topic formulated as a question" (2021D28); "and the presentation (if interestingly formulated, automatically more activity on the topic)" (2022D42). The demanding nature of the participants in constructing the meaning of the task creates high expectations for the lecturer in terms of the student's outcome.

The results of the qualitative study show the exceptional importance of the task for students' engagement in the task. A category of Task-Related Requirements (Table 2) has been identified, consisting of six subcategories: task requirements; lecturer requirements; necessity of the task; link to assessment; limited time and absence of restrictions on the expression of opinion.

TABLE 2. THE CONSTRUCT OF THE CATEGORY OF TASK-RELATED REQUIREMENTS

Category	Subcategory	Statements
Task-Related Requirements	Task requirements	"task requirements" (2021D34);
	Lecturer requirements	"lecturer requirements" (2021D4);
	Necessity of the task	"The thing that drives activity the most is the need to report" (2021D30);
	Link to assessment	"direct link to assessment" (2021D19);
	Limited (restricted) time	"limited time for discussion" (2022D57);
	Absence of restrictions on the expression of opinions	"can be answered afterwards, without forgetting what the

		discussion question is" (2022D46);
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To engage PhD students in a virtual discussion, the lecturer needs to think carefully about each stage of the discussion or criterion, and to prepare the task very carefully. Moreover, learners want to be given a grade for their participation: *"a direct link to the grade"* (2021D19). It is likely that several PhD students are not willing to engage in virtual discussions. They prefer to exchange the latter for live interaction: *"direct link to the grade. The films are very interesting, thought-provoking. We discussed in the family, but on Moodle, only as much as needed"* (2021D19). Engagement in virtual communication is pre-determined by the need to complete a task and receive evaluation. It may even be a pre-determined self-limitation to spend a limited amount of time in virtual space. Discipline in scheduling time spent on the computer and being physically active is a conscious choice [28].

The virtual discussion method should be part of the cumulative score, as the participants have a clear extrinsic motivation. Personal or professional improvement is not a sufficient reason to participate in an activated learning activity: *"the fact that the discussion is part of the overall assessment is what makes it active. If it were just an optional thing and not compulsory, I think there would be very few participants"* (2021D12). Further research is required to obtain data on the limited time available for the task: *"limited time for discussion"* (2022D57). Identifying the reasons behind the request for a limited time can be challenging. They may originate from external discipline that prevents task delays or from a reluctance to engage with a single topic for an extended period. Other possibilities exist, but in this case they remain speculative. However, the data from the study allow us to identify the learners' need not to do all the learning activities here and now, but to choose a more convenient time: *"the possibility of expressing an opinion over a period of time, rather than having to discuss it here and now, as in a lecture"* (2021D2).

The findings confirm the results of other studies that show the convenience of virtual learning. And learners value convenience. This issue may also be the subject of further research, as at this point we can only speculate on the reasons for this demand. It may be necessary to create a learning environment that is conducive to self-directed learning and to be able to immerse oneself in the analysis of a topic without interference. However, it could also be the inability to concentrate on a lecture for a variety of reasons, or even the avoidance of active learning activities, or the tendency to procrastinate on work, etc. Identifying these reasons would help the lecturer to formulate tasks taking into account more students' needs. This results in a coherent system of the study process.

The largest category of this qualitative study is Theme Features (Table 3), which includes as many as twenty-one sub-categories.

TABLE 3. THE CONSTRUCT OF THE CATEGORY OF TOPIC FEATURE

Category	Subcategory	Statements
Topic Features	Topic uniqueness	"topic uniqueness" (2021D18);
	Topic depth	"topic depth" (2022D41);
	Topic width	"topic breadth" (2022D45);
	Provocative topic	"a question that should provoke a person to have an opinion <...>" (2021D1);
	Controversial topic	"Objects that raise many topics for discussion are selected. Discussion is active when a lot of controversial issues are encountered, best of all when the views do not coincide." (2022D43);
	Intriguing topic	"intriguing topic" (2021D36);
	Interesting topic	"interesting topics" (2021D29);
	Engaging topic	"hooks from the first sentence" (2021D38);
	Interesting topic	"appropriate and interesting selection of the task" (2021D31);
	Relevant topic	"relevance of the topic" (2022D42);
	Timely topic	"and certainly a timely discussion" (2021D13);
	Important topic	"the importance of the topic" (2022D54);
	Topic understandable to everyone	"<...> and understandable to everyone (2021D1) "
	Clear topic	"clarity of topic" (2021D34);
	Straightforward topic	"Clear parallel of topic with the film, so that it is clear what to connect the examples with" (2021D18);
	Specific topic	"specificity of the topic <...>" (2022D54);
	Simple topic	"The topic should be simple" (2022D47);
	Easy topic	"easy topic" (2021D7);
	Superficial topic	"superficial topic" (2021D7);
	Emotional topic	"emotional impact" (2022D45);
	(In)compatibility of the topic with the person's point of view	"Does this align with my own interests, personal values" (2022D50);

The qualitative research data allowed us to construct a category with several internal contradictions. This category suggests the distinct individuality of the modern learner. At the same time, it also refers to the unattainable ambition of creating a task and a topic that are suitable for all students. The lecturer's work has become obviously complicated and complex, requiring active, continuous listening, and empathy.

Classically, the topic to be analysed must be very clear, simple (*"the topic must be simple"* (2022D47)) and understandable (*"understandable to all"* (2021D1)). Interpretations and puzzles are not desirable. Clarity of the topic is preferred to a straightforward level: *"1) clarity and simplicity of the topic of discussion 2) uniqueness of the*

topic 3) clear parallelism of the topic with the film, so that it is clear to which to relate examples" (2021D18). The data suggest that learners are not inclined to interpret, analyse and find new meanings or to search for a philosophical source. Extrinsic motivation and the need for quick answers dictate that the topic must be interesting (*"interesting idea"* (2021D25)), engaging (*"hooked from the first sentence"* (2021D38)), relevant (*"relevance of the problem or issue"* (2021D22)), and important (*"importance of the topic"* (2022D54)). A number of participants in the study do not want easy and/or simple topics. They dislike *"superficial topic"* (2021D7) or *"uncomplicated (populist (in the good sense of the word)) issues"* (2021D7). Some of the informants' statements even contradict the idea of the debate method. It is argued that activity in a virtual discussion should be stimulated by the relevance of the topic to the student's existing point of view (*"does it fit with my own interests, personal values"* (2022D50)).

As a contradiction to a simplified topic, the need expressed by other research participants includes a complex topic. Learners are interested in the *"uniqueness of the topic"* (2021D18), the *"depth of the topic"* (2022D41), the *"breadth of the topic"* (2022D45). Additionally they value *"intriguing topic"* (2021D36) and provocation. Human curiosity to know, discover, and explore leads to such topics [29]. The provocation of a question is associated with the need to have an opinion [13] (*"a question should provoke someone to have an opinion. It has to be relevant and understandable to everyone"* (2021D1)). When provoked, there is an implicit pressure to have something to say or to offer a reaction. However, the study did not find any indication of the need of the participants to know the topic, to have practical experience or to have inside experience. It can be argued that the PhD students in the study are more focused on the outcome of the teacher's work (the topic and the task presented) rather than seeking to build their own competence or experience with the topic. The study did not reveal the learner's self-demanding nature.

The learning process, especially the discussion method, requires *"emotional impact"* (2022D45). Discussions can be organised to stimulate physically expressed reactions to the ongoing discussion. For example, clapping, tapping feet, shouting contribute to the positivity, attractiveness and even the quality and success of the discussion in achieving the goal. They are also a symbolic reminder that the aim of the debate is to eliminate ignorance and reduce misunderstanding of reality. In such cases, silence is treated as a lack of debate [30]. It should be noted that such physical expression of emotions must be agreed upon in advance of the debate method. Instead, in response to the research participants' need for emotions, an agreement can be reached on expressing emotions in a virtual discussion.

A virtual debate is organised on a platform. The functionality and interactivity of this platform is revealed in the category of Requirements for Virtual Discussion

Platform, which is made up of seven sub-categories: accessibility; usability of the platform; simplicity of the platform; interactivity; visuality; anonymity; and participant information (Table 4).

TABLE 4. THE CONSTRUCT OF THE CATEGORY OF REQUIREMENTS FOR VIRTUAL DISCUSSION PLATFORM

Category	Subcategory	Statements
Requirements for Virtual Discussion Platform	Accessibility	<i>"convenient time and place"</i> (2022D60);
	Platform usability	<i>"usability of the system (some features were very cumbersome and unclear to use)"</i> (2021D3);
	Simplicity of the platform	<i>"ease of engagement"</i> (2022D45);
	Interactivity	<i>"interactivity"</i> (2021D15);
	Visuality	<i>"visual aids"</i> (2021D15);
	Anonymity	<i>"anonymity"</i> (2022D55);
	Participant information	<i>"participant's photo and short info about him/her"</i> (2021D27);

The results of the qualitative study show that the user-friendliness of the platform also determines the engagement of a person in virtual discussions: *"ease of use of the platform"* (2021D27). Virtual space has made people feel free to use the virtual world without any preparation. Virtual space is work, leisure, play, learning and simply communication and it should provide a sense of freedom and comfort. If there is a need to spend extra time learning the rules, people tend to refuse to use such a platform.

Various rules, tips, manuals, and etiquette books have been developed to facilitate lively communication. People care about who they interact with, so research is conducted and recommendations are developed on how to make a good impression, how to present oneself, and how to bring out one's best side during the first meeting. In a virtual space, many things are different, but people remain the same. In the virtual world, it is still important who we engage with, who we learn from, and whose thoughts or ideas we encounter. The results of the qualitative study show that participants in a virtual discussion are more engaged in the discussion when they have visual and verbal information about other participants in the virtual discussion: *"A picture of the participant and a short info about him/her"* (2021D27). When designing machine learning, it is important to note that to engage the learner in the proposed activity, it is necessary to have a user-friendly (intuitive) platform; visual and verbal information about the participants, and maybe a robot that will become a full participant in the discussion. Based on this information, it is possible to create information about the participants in virtual interaction in a variety of different expressions: photos, video footage, textual and auditory information, etc., as the available technologies allow. However, other informants express a contradictory wish to remain anonymous on the virtual discussion platform (2022D55). This is another contradiction that complicates the creative

processes for both the participants in the virtual discussion and the lecturer.

The category of Virtual Discussion Activity is made up of three subcategories: learner motivation; interested audience and peer engagement (Table 5).

TABLE 5. THE CONSTRUCT OF THE CATEGORY OF VIRTUAL DISCUSSION ACTIVITY

Category	Subcategory	Statements
Virtual Discussion Activity	Learner motivation	"students' own motivation to engage in the discussion" (2021D9);
	Interested audience	"interested audience" (2021D29);
	Peer engagement	"engagement of other colleagues" (2022D41);

Research participants observe that engagement in a virtual discussion requires "interest in the presented topic" (2021D10). When there is interest, curiosity and the joy of discovery lead to active participation [29]. This, in turn, encourages greater involvement from learners ("peer engagement" (2022D49)). While a number of students are driven by motivation ("intrinsic motivation to complete the task" (2022D51)), others may feel uncomfortable staying on the sidelines. Following a positive example creates conditions for deeper learning, exploration, and experience. Therefore, the dissemination of good practices, analysis of successful examples, student activation, and publicising student engagement are key factors in promoting student activity.

The category of Nature and Structure of Communication consists of seven subcategories: ability to analyse; ability to express an opinion; formulation of answers; colleague responses; diversity of opinions; receiving a response promptly; and opportunity to think about the answer (Table 6).

TABLE 6. THE CONSTRUCT OF THE CATEGORY OF NATURE AND STRUCTURE OF COMMUNICATION

Category	Subcategory	Statements
Nature and Structure of Communication	Ability to analyse	"interest in analysing various situations" (2022D56);
	Ability to express an opinion	"ability to express an opinion freely" (2021D2);
	Formulation of answers	"current matters: "<...> short and clear answers" (2022D39);
	Colleague responses	"reasoned, interesting answers..." (2021D26);
	Diversity of opinions	"the topic must be debatable, there can be several correct points of view" (2022D55); "find like-minded people" (2021D33);
	Prompt response	"quicker response" (2022D46);
	Opportunity to think about the answer	"It is not necessary to reply at once, you can think about your answer or opinion" (2021D14);

Similarly as in real life, the need to belong to a community and find like-minded individuals persists in virtual spaces: 'interest in virtual communication, the desire to express one's opinion, and to find like-minded individuals' (2021D33). According to the principles of A. Maslow's hierarchy of needs [31], [32], once physiological and safety needs of a person are met, the need for belonging emerges. This is a key factor when integrating machine learning into education. It is essential to consider how the learner's sense of security will be established and maintained. Otherwise, the learner may be inclined to perform only the necessary actions and quickly move to other platforms or return to the real world. The students show interest in thoughts and opinions of each other: "Key factors: a 'hook' on the topic, a short and clear question, short and clear answers" (2022D39).

Any form of communication requires emotional engagement. If an activity does not evoke emotions, it does not encourage interaction. The results of the qualitative study indicate that emotions can be triggered not only by the topic itself but also by the arguments presented by peers. It is the diversity of arguments that can spark interest in participating in a virtual discussion: "personal interest in the topic, its relevance, and arguments that provoke a desire to either contradict or expand upon them" (2022D53); "the alignment or misalignment of participants' viewpoints. It is important that people do not simply respond but express their opinions with reasoning, sometimes even with enthusiasm" (2022D58).

This perspective aligns with the essence of the discussion method, which aim to acquire knowledge and analyse phenomena from multiple viewpoints [13]. Socratic pedagogy is particularly significant, as it teaches participants not to shy away from contradictions, encouraging them to delve deeper into their own arguments and fostering self-reflection. According to Maceina, modern pedagogy "follows the path paved by Socrates" [33: 493].

Research participants state that they appreciate when others respond quickly and provide immediate answers; however, they also value the opportunity to respond later at their own pace: "responses are given quickly, but there is also the possibility of replying later without forgetting the discussion question" (2022D46). These findings reflect the needs of contemporary learners, who seek fast results and prefer a rapid exchange of information.

The category of Social Interaction consists of six subcategories: opportunity to communicate; lack of face-to-face interaction; irreplaceability of face-to-face communication; virtual communication; availability of free time; and benefits received (Table 7).

TABLE 7. THE CONSTRUCT OF THE CATEGORY OF SOCIAL INTERACTION

Category	Subcategory	Statements
Social Interaction	Opportunity to communicate	"desire to communicate" (2022D56);

	Lack of face-to-face communication	"The lack of live communication between people is one of the reasons" (2021D20);
	Indispensable nature of face-to-face communication	"I think the discussions would have been more engaging if we had discussed live" (2022D40)
	Virtual communication	"interest in communicating virtually" (2021D33);
	Having free time	"having extra free time" (2022D42);
	Received benefit	"A clear understanding of the value, what it gives you, for what purpose I do it" (2022D50);

The qualitative study reveals the issue of loneliness: "The lack of face-to-face communication is one of the reasons" (2021D20). Loneliness in the age of technology is widely discussed by researchers in various fields [34], [35], [36]. Although technology has been found to reduce loneliness among older adults [37], [38], virtual communication among young people remains a topic of debate. According to Scott Lash (2002) [39], the growing popularity of the internet contributes to the experience of loneliness. Constant online activity significantly impacts people's interactions with their families and friends, reducing direct participation in community life. Lash argues that the internet can be seen as a technology of complete separation, promoting isolation, individualism, and anti-socialization [39], [40]. In the 21st century, the cycle of transmitting valuable wisdom from generation to generation has changed. Today, certain competencies necessary for survival, life, and self-realisation are higher in young people. This may reduce the need for a young person to communicate with an older person, drawing on experience and wisdom. This fact not only reduces communication between generations but also increases the gap and stronger desire to communicate virtually. Paradoxically, "although people are together online, they remain alone" [41: 5634]. Doctoral students studying at university can compensate for the lack of live communication by participating in virtual discussions: "desire to communicate" (2022D56); "interest in communicating virtually" (2021D33). Such involvement in virtual communication can encourage writing comments, expressing opinions, and thus spending more and more time in the virtual space.

An interesting fact is that the activity of the study participants in the virtual space can be determined by the availability of free time: "the presence of additional free time" (2022D42). Participation in the virtual space is not treated as a learning process. Only the remaining time from other life activities will be allocated to this task. Also, activity is encouraged by the perception of meaning in the activity: "a clear understanding of the value, what it gives you, for what purpose I do it" (2022D50). It is difficult to find the motivation to invest time in activities whose value and benefits are questionable.

IV. CONCLUSIONS

Virtual discussions have an undeniable advantage over live discussions when it comes to individualising tasks. The form and nature of virtual discussions respond to the diversity of individualised needs, ensuring flexibility and the ability to choose the time and pace of participation. Virtual discussions, by their nature, adapt to the needs, desires, and lifestyle of the student without additional effort on the part of the teacher.

Effective virtual discussions depend on clear topics, a convenient platform, emotional engagement and social interaction, and participants' engagement is often determined by their motivation and time. The demands of research participants on the topic are so contradictory that it is almost impossible for the teacher to respond to all the needs of the learners with a formulated task. Some students need an engaging, timely, provocative topic, while others ask for a clear, concise, specific or even straightforward one. The motivation of doctoral students is often based on getting evaluation rather than deep learning.

Students value emotional connection and the opportunity to get to know other participants, so it is important to create a platform that allows them to express themselves and their emotions in various forms. The need for learners to experience emotions is evident in several aspects. Students want to have the opportunity to experience emotions on the virtual discussion platform itself by receiving information about other discussion participants. When designing future prospects, it is also worth considering the personalisation of virtual learning environment robots. This can be compared to the process of getting to know each other during live communication. A virtual learning platform can provide various forms of self-presentation: photo, video, text, etc. Having attractive formats can give the platform a competitive advantage over other virtual learning environments. The participants in the study would like to express their emotions during the discussion itself. The search for diversity and attractiveness of emotional expression can provide many benefits to virtual learning platform developers in creating the attractiveness of the platform and the active involvement of participants in learning activities. It should be noted that some participants in the study are active in the virtual discussion only if they can remain anonymous. In addition, the opportunity to find like-minded people and hear different opinions during the discussion also raises emotions for the learners. The gathering of communities and/or like-minded people is an emotional and important moment for the expression of personality.

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Integrated Learning of Laminar Boundary Layer Modeling on Flat Plates Using ANSYS Workbench for Ship Machinery Mechanics and Mechatronics Specialists

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Abstract—In engineering disciplines such as ship machinery mechanics and mechatronics, the ability to model and simulate physical phenomena is essential for designing and optimizing complex systems. One of the fundamental topics in fluid mechanics is the laminar boundary layer over flat plates, which plays a crucial role in understanding drag forces, heat transfer, and flow behaviour in naval and mechatronic applications. Accurate modelling of the boundary layer is essential for improving the performance of ship propulsion systems, reducing energy losses, and enhancing the efficiency of fluid-based mechatronic devices. This study presents an integrated learning approach that leverages ANSYS Workbench as a computational tool for teaching and understanding the laminar boundary layer modelling over flat plates. The primary objective is to bridge the gap between theoretical knowledge and practical application by incorporating simulation-based learning into engineering education. By integrating computational fluid dynamics (CFD) simulations with classical theoretical models, students develop a deeper understanding of boundary layer development, velocity profiles, and shear stress distribution. The methodology involves a structured learning process where students first study the fundamental equations governing laminar boundary layers, such as the Blasius solution for incompressible flow over a flat plate. They then proceed with hands-on simulations in ANSYS Fluent, where they define boundary conditions, mesh the computational domain, and analyse numerical results in comparison with analytical solutions. The learning approach encourages active problem-solving and enhances critical thinking skills. The findings demonstrate that simulation-based learning significantly improves students' comprehension of boundary layer theory by visualizing complex flow phenomena. Additionally, the integration of CFD tools fosters practical skills in numerical modelling,

which are essential for their future careers in ship machinery mechanics and mechatronics. The proposed method enhances student engagement and provides a systematic framework for applying CFD techniques in engineering education, reinforcing the importance of simulation in modern fluid mechanics.

Keywords— *laminar boundary layer, flat plates, ANSYS Workbench, integrated learning, ship machinery mechanics, mechatronics, fluid dynamics.*

I. INTRODUCTION

The modelling of laminar boundary layers on flat plates represents one of the fundamental problems in fluid mechanics and finds wide application in engineering practice. This topic is of relevance to the Ship Machinery and Mechanisms and Mechatronics disciplines as it involves the development of solutions for the optimization of the aerodynamic and hydrodynamic performance of structures and machinery used in the marine and industrial domains. This paper discusses an integrated approach for laminar boundary layer modelling training using ANSYS Workbench, a powerful numerical simulation tool.

A. Theoretical basis

Boundary layer theory, a cornerstone of modern fluid mechanics, was introduced by Ludwig Prandtl in the early 20th century and further advanced by researchers such as Hermann Schlichting [1]. It describes fluid flow behavior near solid boundaries, where viscous effects dominate, and velocity gradients are significant. One classical and extensively studied case is the laminar boundary layer over

Online ISSN 2256-070X

<https://doi.org/10.17770/etr2025vol3.8520>

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a flat plate, where the velocity profile evolves from zero at the wall to the free-stream value away from it.

Schlichting's *Boundary-Layer Theory* [1] and White's *Fluid Mechanics* [2] provide a comprehensive theoretical framework for analyzing such flows. These works explain the derivation and implications of the Blasius solution — a simplified yet fundamental, analytical solution of the Navier-Stokes equations for steady, incompressible, two-dimensional laminar flow over a flat surface.

The importance of this theory extends into practical modeling through Computational Fluid Dynamics (CFD). Anderson's textbook [3] introduces the fundamental principles of CFD and explains how analytical models like the Blasius solution can be validated and extended using numerical techniques.

Cengel and Cimbala [4] elaborate on the physical interpretation of boundary layer formation and offer detailed worked examples, bridging theoretical and applied perspectives.

More specialized CFD references such as Tu et al. [5] and Moukalled et al. [6] present methods for discretizing the governing equations (e.g., using the finite volume method), which are commonly implemented in tools like ANSYS Fluent. These sources offer guidance on constructing computational mesh, setting boundary conditions, and achieving convergence in simulations.

Blazek's volume [7] adds deeper mathematical and physical rigor, providing a robust foundation for those interested in the development of CFD algorithms, including turbulence modeling and advanced solver techniques.

Additionally, Munson et al. [8] provides a broad overview of fluid mechanics fundamentals that support the understanding of laminar boundary layers in both theoretical and experimental contexts.

Given the educational focus of this study, integrating CFD with classroom learning aligns with the principles of inductive teaching described by Prince and Felder [9], where students build theoretical understanding through hands-on simulations.

This theoretical foundation forms the basis for the integrated learning approach developed in this study, combining classical boundary layer theory with numerical modeling through ANSYS Workbench.

ANSYS Innovation Space (2023) [11]: The online ANSYS tutorial on flat plate laminar boundary layers

offers a practical guide to setting up simulations, defining mesh parameters, and analyzing CFD results.

B. Importance of Engineering Practice

In engineering practice, laminar boundary layer analysis is important for the design of energy efficient systems and devices. In the field of ship machinery and mechanisms, for example, understanding the fluid-structure interaction is critical to reducing hydrodynamic drag and optimizing energy consumption. In mechatronics, on the other hand, boundary layers influence the thermal management and aerodynamic performance of mechanical systems.

Numerical modelling using ANSYS Workbench provides powerful tools to simulate and analyze these complex processes. The software allows the solution of Navier-Stokes equations and the visualization of the results, facilitating both the understanding of the phenomena and their application in the real world.

C. Educational context

Laminar boundary layer training is a valuable element of the curriculum for students in engineering degree programs. Combining theory with practical application through ANSYS Workbench, [10], students can develop critical analysis and design skills. Incorporating realistic projects and simulation-based tasks allows academic knowledge to be linked to industrial applications.

In the specialties "Ship Machinery and Mechanisms" and "Mechatronics" the integrated training includes:

Theoretical background: understanding of the basic principles of fluid mechanics and boundary layer theory.

Practical exercises: using numerical methods to simulate boundary layers on flat plates.

Project-Based Learning: Solve engineering problems using ANSYS Workbench, focusing on visualization and interpretation of results.

D. Objectives of the article

This study aims to develop an integrated learning approach that combines theoretical boundary layer analysis with hands-on numerical simulations using ANSYS Workbench. The key objectives are:

- To introduce students and researchers to theoretical concepts underlying laminar boundary layer formation.
- To provide a step-by-step guide for modeling boundary layer development using ANSYS Fluent.
- To compare analytical solutions, experimental data, and numerical results for enhanced understanding.
- To evaluate the effectiveness of simulation-based learning in engineering education by assessing student engagement and comprehension.

To highlight practical applications in naval engineering and mechatronics, demonstrating how

boundary layer modeling contributes to optimizing energy efficiency and system performance. With its interdisciplinary nature and emphasis on practical application, the paper aims to contribute to the improvement of teaching methodologies and to promote the use of modern technologies in engineering education.

E. Importance in Ship Machinery and Mechatronics

- In ship machinery, the drag force on a ship's hull is directly influenced by the boundary layer, affecting fuel efficiency and operational costs. In mechatronic systems, understanding boundary layers can improve the design of fluid-based components, such as actuators and pumps, leading to more efficient and reliable systems

II. MATERIALS AND METHODS

A. Laminar boundary layer modeling -problem specification

Figure 1 shows Specification of the flat plate laminar boundary layer problem.

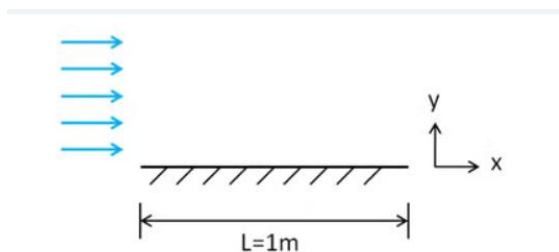


Fig. 1 Flat plate boundary layer problem.

An experimental and theoretical investigation into the development of a laminar boundary layer over a flat plate at a Reynolds number of 10,000 is conducted. Numerical simulations using ANSYS Workbench are employed to determine the velocity and pressure distributions within the boundary layer. The obtained results will be compared with classical solutions for laminar boundary layers. This research is part of a broader project aimed at deepening the understanding of boundary layers and their applications in marine machinery and mechanisms. To accomplish the task of this research, the approach given in the source, [11] was used.

If the steps given in source [11] are followed, before proceeding to drawing the geometry of the flat plate, a preliminary analysis of the problem of this article is made. First, a suitable mathematical model must be specified and it must be seen what boundary conditions will be set. The problem in this present article is solved following the approach [11]. After clarifying the mathematical model, a numerical solution strategy is set. The geometry of the flat plate, which is specified as a domain, is divided into a certain number of control volumes or cells. The problem is optimized by determining the values of the velocities and pressures for each center of the cell. Interpolation of each center of the cell is used to determine the values of the other cells. This step is called discretization, and

namely, after drawing the geometry of the model, a computational network is built. Then, following the approach [11], it is discussed analytically how many differential equations are solved, namely the Navier-Stokes equations, in order to clarify the behavior of the velocity profile through the flat plate.

After a preliminary analysis of the modeled object has been performed, including clarification of the mathematical model, the numerical solution strategy, and hand calculation, the next step is drawing the geometry of the object.

B. Flat plate geometry

Fig. 2 shows the drawn geometry of the object-flat plate into environment Space Claim into ANSYS.

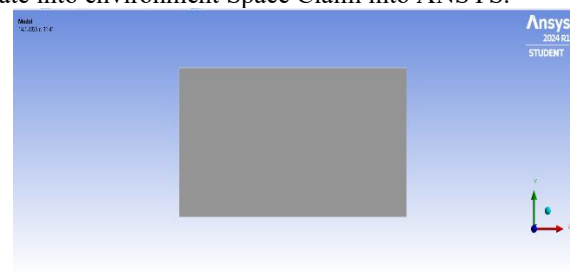


Fig. 2 geometry of flat plate

The geometry is drawn following the approach [11]. The study deals with conducting laminar boundary layer modeling over the flat plat.

C. Numerical mesh

In order to achieve the goal of the present study, namely the successful modeling of a laminar boundary layer around a flat plate and following approach [11], a procedure for creating a hex mesh around the object was performed. Fig. 3 shows the numerical mesh created around the object.

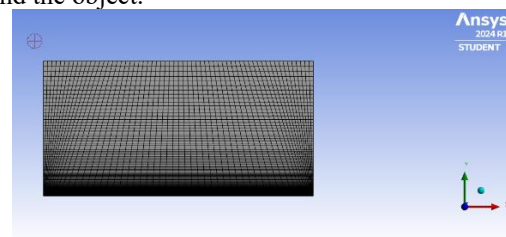


Fig. 3 Mesh around the flat plate

To capture flow behavior near the flat plate, the mesh must be refined near the boundary. Following the approach [11] and as can be seen from Fig. 3 the mesh is refined at the flat plate boundary using edge biasing control. According to statistics given in ANSYS the mesh consists of 6200 elements.

D. Physical Setup

After the successful construction of the computational mesh, a physical setup of the model was performed, [11]. Laminar flow was chosen as the viscous

model and the following assumption was made that the modeled fluid flow is two-dimensional, steady, incompressible and Newtonian.

E. Numerical Solution

Following the procedure according to source [11] the next step to fulfill the purpose of that study is to run the solution of the problem into ANSYS Fluent and to set up the residual criteria.

III. RESULTS AND DISCUSSION

Convergence is crucial for modeling laminar boundary layer. As the iterations go on, the key parameters are expected to stop changing. At this point, the simulation is considered converged. For modeling the behavior of laminar boundary layer over the flat plate the key parameters for convergence that must be monitored are velocity vectors, velocity magnitude contours, pressure contours and velocity profile.

Fig. 4 and Fig. 5 show from afar and up-close velocity vectors after formulation and development of the laminar boundary layer around the flat plate.

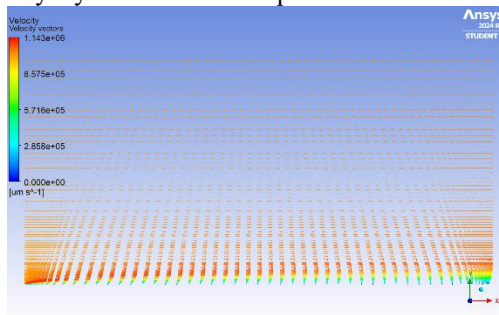


Fig. 4 Velocity vectors afar.

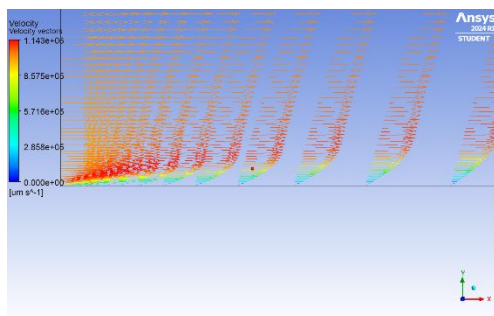


Fig. 5 Velocity vectors up-close.

Observing Fig. 4 and Fig. 5 velocity vectors show a nice view of the boundary layer development and if we go over the range the velocities go from zero to a little over one, which is what we expected. The closer look of a boundary layer over the plate shows that in the beginning the boundary layer is uniform then quickly it gets established and then it grows slowly.

Fig. 6 shows the velocity magnitude contours.

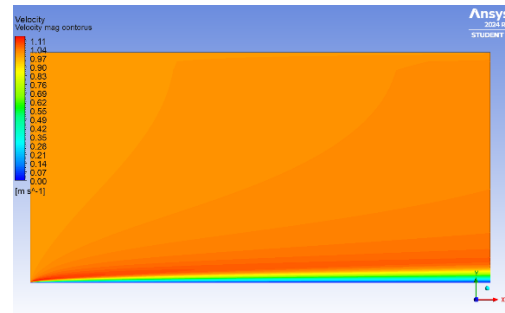


Fig. 6 Velocity mag contours.

Velocity mag contours, Fig. 6 show the development of boundary layer and, we can see thickness of the boundary layer that is much smaller than the length of the plate which is what we expected. We can also probe values of velocity using probe command from ANSYS. From the right side of the plate where we see the red contours, the boundary layer transitions into the outer flow. The velocity is around 1 which is what we expected. Near the farfield 1 and farfield 2 the velocity value is close to one and then near the plate it is at zero which is what we expect.

Fig. 7 shows the pressure contours after modeling laminar boundary layer over the flat plate.

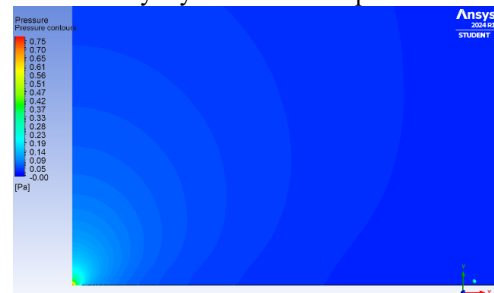


Fig. 7 Pressure contours.

Into the pressure contours we see the variation of pressure. If we come to leading edge, we see that we get relatively high pressures here now boundary layer theory breaks down over here and fluent solution is valid in the leading edge, but we get very rapid boundary layer development over here. Away from the left corner of the graph we can see that the gauge pressure is almost zero and so we go through the boundary layer and since the pressure is not very much the partial derivative of pressure by y is very close to zero and that is what we expect and that matches with our expectations from boundary layer theory. If we look at the range of gauge pressure, we should compare it to the free stream dynamic pressure which has half density goes infinity squared which is equal to 0.5. Path blue regions indicated the gauge pressure variation is very low which meets with our expectations from boundary layer theory. The gauge pressure, especially as you get closer to the plate, deviates from zero to 0.17. Fig. 8 shows the comparison between the pressure contours and the velocity magnitude contours.

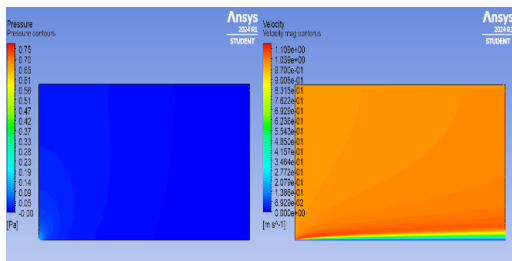


Fig. 8 Pressure contours versus velocity magnitude contours.

Pressure contours & velocity mag contours from here you can see that the boundary layer does not have much effect on the pressure whereas it has a big effect on velocity where velocity is going from 0 to 1.

Fig. 9 shows the velocity profile at the flat plate. Velocity profile at the plate is zero and then it increases as we move away from the plate in the Y direction. From boundary layer theory we expect it to go to 1 here it's overshooting by about 10% and then it decays to one. The overshooting is an artifact of the displacement thickness of the boundary layer it's a finite Reynold number of fact as you increase Reynold number this overshoot becomes smaller and smaller.

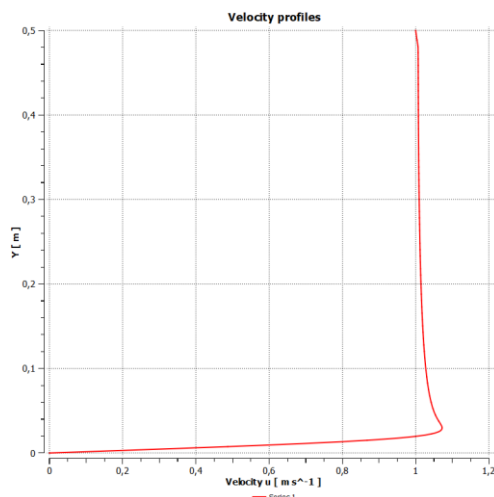


Fig. 9 Velocity profile at the flat plate.

Fig. 10 shows again the velocity profile with some changes and improvements.

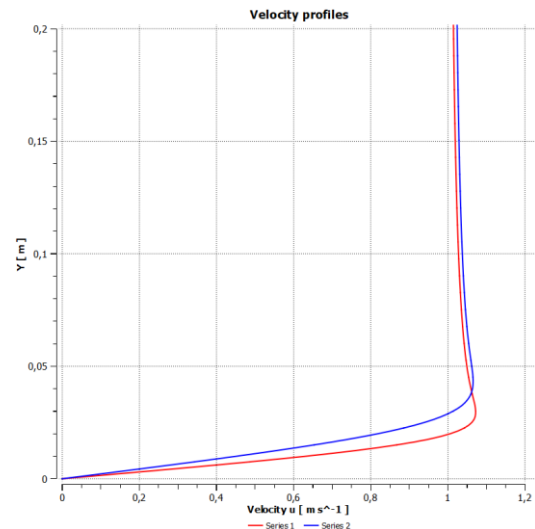


Fig. 10 Velocity profile 2.

Velocity profile 2, Fig. 10 shows the effect of the boundary layer thickening, the boundary layer ends approximately equal to close to 0.05 so that is the same ballpark as our estimate for the boundary layer thickness at the end of the plate using boundary layer theory. From the graph of velocity profile 2 we will discuss velocity profile overshoot, including why the velocity at the boundary layer edge is on the higher side of that free stream. Overshoot in the velocity profiles that we see on the graph is a real effect that you get by solving Navier-Stokes equations with fluent that is missed by boundary layer theory. Boundary layer theory splits the flow into an inner flow and outer flow. The inner flow is where the boundary layer equations are valid in the outer flow. The boundary layer theory assumes that the boundary layer is very thin so it's just a flow past flat plate. However, if you think about the outer flow as it's getting displaced as it's moving along the fluid it's going to accelerate. So, the velocity profile is zero at the wall and then it increases and at the edge of the boundary layer it's not one it's slightly higher than one because of the acceleration effect.

IV. CONCLUSIONS

This study presents an integrated approach to modeling laminar boundary layers over flat plates by combining theoretical analysis with numerical simulations in ANSYS Workbench. The results demonstrate the effectiveness of using Computational Fluid Dynamics (CFD) tools in engineering education, providing students and researchers with a deeper understanding of boundary layer development and its implications in practical applications.

A. Theoretical Applications

- From a theoretical standpoint, the study validates the classical boundary layer theory, particularly the Blasius solution, which describes the velocity profile and boundary layer growth for an incompressible,

steady laminar flow over a flat plate. The numerical results closely match the expected boundary layer behavior, including:

- The gradual formation and thickening of the boundary layer along the plate.
- The velocity profile's transition from zero at the wall to its free-stream value, with an overshoot due to displacement effects.
- The near-zero pressure gradient in the boundary layer, aligning with theoretical predictions.
- These findings confirm the accuracy and reliability of classical fluid mechanics principles, reinforcing their continued relevance in modern engineering analysis. Additionally, by comparing analytical and numerical solutions, students gain a quantitative understanding of fluid behavior and numerical approximations.

B. Practical Applications

The practical significance of laminar boundary layer modeling extends to multiple engineering fields:

C. Naval Engineering and Ship Machinery

- Understanding boundary layer effects is crucial for reducing hydrodynamic drag on ship hulls, leading to improved fuel efficiency and lower operational costs.
- CFD simulations help in designing more hydrodynamically efficient hull structures by optimizing surface smoothness and shape.

D. Mechatronics and Fluid-Based System

- In mechatronic applications, boundary layer phenomena influence thermal management, lubrication efficiency, and aerodynamics of mechanical components.
- CFD modeling provides insights for optimizing fluid-based actuators and pumps, ensuring efficient operation and reduced energy losses.

E. Aerospace and Automotive Engineering:

- Although not the primary focus of this study, similar boundary layer principles apply in airfoil design, drag reduction strategies, and heat transfer optimization in various engineering sectors.

F. Educational Impact and Future Prospects

- This integrated learning approach enhances engineering education by fostering:
- Active problem-solving skills through hands-on CFD simulations.
- A deeper conceptual understanding of boundary layer physics beyond textbook learning.
- Improved computational proficiency, preparing students for advanced CFD applications in industrial settings.
- Future research could extend this approach to turbulent boundary layers, explore 3D flow effects, or integrate experimental validation with laboratory tests for further verification of CFD models.

In conclusion, the combination of theoretical foundations and numerical simulations in engineering curricula significantly enhances both learning outcomes and practical competencies, bridging the gap between academic knowledge and real-world engineering applications.

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Usage of an Interactive Electronic Textbook Application: Reflection of Ukrainian Experience (Based on the Integrated Course “Health, Safety, and Well-Being”)

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Abstract—In 2018, a full-scale reform of general secondary education called “The New Ukrainian School” was launched in Ukraine. The reform will continue until 2029 and aims to update educational content to develop students' competencies and cross-cutting skills necessary for successful personal and professional realization; employ active learning methods; create an innovative and inclusive educational environment; and enhance preparation for future professional and educational trajectories. In this context, pedagogical science and practice face a number of complex and responsible tasks related to the implementation of effective learning models that extensively use digital and interactive technologies, ensuring the formation of lifelong learning competencies (Recommendations of the European Parliament and the Council of the European Union). An important tool for effective learning is an interactive electronic textbook application, which significantly expands the capabilities of a printed textbook through multimedia content and interactive functions. The development of such an application requires not only compliance with the current regulatory framework of Ukraine but also an examination of best practices in the use of electronic textbook applications in the educational theory and practice of European countries. This article is written by the authors of school textbooks for the integrated course “Health, Safety, and Well-Being” for the 7th and 8th grades of the New Ukrainian School. The aim of our study is to theoretically justify and empirically examine the functionality and content fullness of the

interactive electronic application to the “Health, Safety, and Well-Being” textbook. The theoretical and experimental study was conducted during 2023-2024 in general secondary education institutions in Ukraine that used the authors' textbook in the educational process. The study involved 600 respondents – school teachers. Our research addressed three main objectives: 1) to analyse the experience of European countries in developing and implementing interactive electronic textbook applications to integrate best practices into the Ukrainian educational space; 2) to conduct a pilot implementation of the interactive electronic application developed by the authors; 3) to identify the factors and conditions that enhance the effectiveness of using an interactive electronic textbook application. The article describes the stages of the research, provides an analysis of the best European practices in using electronic applications to school textbooks, and presents the interactive electronic application developed as a result of this study for the “Health, Safety, and Well-Being” integrated course for the 7th and 8th grades of the New Ukrainian School. The article also includes an analysis of empirical data obtained during the research.

Keywords—Electronic learning tools, interactive electronic application, interactive functions, multimedia content, teaching methods, textbook.

Online ISSN 2256-070X

<https://doi.org/10.17770/etr2025vol3.8528>

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I. INTRODUCTION

Educational strategies in many countries worldwide involve the development and implementation of digital learning resources, the use of which significantly expands students' cognitive abilities and ensures the formation of their competencies in the shortest way possible. Today, digitalization is not merely a technological process or product; it represents a modern approach to creating and utilizing digital materials, which play a crucial role in providing high-quality, continuous education and ensuring equal access to educational resources for students, their parents, and teachers. This necessitates the updating of teaching methodologies and the implementation of new learning tools in accordance with the requirements of the digital environment. This applies particularly to textbooks, which should not merely be content carriers, but also tools aimed at developing students' ability to apply acquired knowledge in real-life situations, serving as an effective instrument for managing cognitive activities. The integration of printed textbooks with their interactive electronic applications enables the realization of the best achievements of both traditional and modern learning through the formula: content+ methodology + computer [1]-[2]. A productive approach today is the strategy of using electronic learning tools as a supplement to traditional teaching methods. Experts emphasize that IT technologies should be integrated into curricula and used alongside other educational tools, such as printed textbooks, artistic materials, written samples, game materials, and books, which together facilitate students' self-expression in various types of activities [3]-[8].

In global pedagogical theory and practice, the use of interactive learning tools has been discussed since the early 1980s [9]. However, the development and implementation of interactive electronic textbooks with multimedia elements, hyperlinks, games, tests, as well as interactive electronic applications to school textbooks over the past decade, have significantly intensified research into their content, functions, and effectiveness [4]-[5], [10]-[13].

M. J. Koehler, P. Mishra, and W. Cain emphasize the need for an effective combination of educational content, pedagogical technologies, and digital tools in learning [14]. They identify electronic textbooks and interactive electronic applications to printed textbooks as the foundation of educational technologization. Research findings indicate that an interactive electronic application to a school textbook promotes independent learning and enables students to organize cognitive activities in different conditions and with varying sets of input data [15].

Today, interactive electronic applications to school textbooks are attracting increasing attention from Ukrainian researchers. This growing interest is not coincidental. In 2018, Ukraine launched a large-scale reform of general secondary education called "New Ukrainian School", which will continue until 2029. The goal of the reform is to update educational content to

develop key competencies necessary for students' successful personal and professional realization, apply active teaching methods, create an innovative and inclusive educational environment, and strengthen preparation for future professional and educational trajectories. As a result, Ukrainian pedagogical science and practice face a number of complex and responsible tasks related to the implementation of effective learning models that widely use digital and interactive technologies to foster lifelong learning competencies (as recommended by the European Parliament and the Council of the European Union).

On the other hand, today's students, who have a modern type of thinking and are adapted to virtual reality, are entering schools. According to the "Generations Theory" (Neil Howe, William Strauss), today's school students belong to Generation Z – "digital" children, the children of multimedia technologies [16]. Ukrainian schoolchildren's learning and cognitive activities are characterized by the ability to quickly perceive and process large volumes of information, easily switch attention from one activity to another, concentrate on multiple information streams, and quickly find the necessary data among a vast amount of information [6], [17]. These characteristics must be taken into account when developing learning tools.

A generalization of theoretical developments, as well as the results of Ukrainian and international research, provides grounds for the following conclusions regarding the use of interactive electronic supplements to school textbooks: this is not about passive technology use where students merely consume content. Instead, an interactive electronic supplement ensures students' active engagement, as they utilize resources for meaningful learning [18]-[20]. This is especially important for teaching integrated courses based on an interdisciplinary approach.

Over the past few years, the authors of this article have been working on creating school textbooks for the integrated course "Health, Safety, and Well-being" within the New Ukrainian School framework. This course addresses the tasks of social and health-preserving educational fields in accordance with the State Standard of Basic Secondary Education through a four-group learning cycle:

- personal health and safety care, risk avoidance, response to factors and activities that have a threat to life, health, and well-being of oneself and others;
- identifying alternatives, predicting consequences, and making decisions beneficial to one's own safety and the safety of others, as well as their health and well-being;
- making an informed choice for a healthy lifestyle, analysing and assessing consequences and risks;

- entrepreneurship and ethical behaviour for improving health, safety, and well-being.

Given the specifics of the integrated course “Health, Safety, and Well-being”, teachers should prioritize active and interactive, creative, and flexible forms and methods of organizing learning activities, fostering active collaboration among all participants in the educational process. These methods include group work, discussions, brainstorming, mind mapping, role-playing games, excursions, problem-solving modelling, debates, research, practical tasks, and project-based learning [20]-[23]. Thus, our primary goal was to create a next-generation school textbook with an interactive electronic application that would fully consider the specific features of the integrated course.

At the time of developing the “Health, Safety, and Well-being” textbook for the 7th grade, there were no regulatory documents in Ukraine defining the content and requirements for interactive applications. Therefore, we²⁾ relied on research findings and international experiences in implementing electronic textbook applications. During the first half of 2023, we analysed a significant array of scientific publications and publicly available information on various aspects of implementing interactive electronic applications for school textbooks. This analysis and the generalization of research results enabled us to design the architecture of the electronic application based on the following key principles:

- 1) the content of the application must align with the textbook’s content and consider its specific features;
- 2) the volume of educational, multimedia, and other content in the application must take into account the technical capabilities of the storage where it is hosted and the characteristics of the devices used to access it;
- 3) the application must include tasks of varying complexity and provide individualized learning trajectories;
- 4) the application must include self-assessment tasks for evaluating learning outcomes;
- 5) the application must contain multimedia elements, tools for interactive engagement, the ability for users to review their accomplishment of interactive tasks, and a user guide explaining the functions of all interface elements;
- 6) the application must not contain advertisements.

Over the next six months, we worked on creating the 7th-grade textbook for the integrated course “Health, Safety, and Well-being” and its interactive electronic supplement (<https://svitdovkola.org/books/zbd7>). In early 2024, the textbook was recommended by the Ministry of Education and Science of Ukraine for use in Ukrainian schools and became one of the winners of the competition for selecting 7th-grade textbooks.

However, in April 2024, the Ministry of Education and Science of Ukraine issued an order approving requirements for interactive electronic textbook applications. This document fully aligns with the conclusions we reached in our research. Our next challenge was to develop a new textbook for the 8th-grade integrated course “Health, Safety, and Well-being” and its interactive electronic application. This new application was created based on the results of the pilot implementation of the 7th-grade application.

II. MATERIALS AND METHODS

Organizing the experimental study, we set the following objectives:

- 1) to develop and conduct the pilot testing of an interactive electronic application for the author’s textbook of the integrated course “Health, Safety, and Well-being” for the 7th grade;
- 2) to study its effectiveness and design ways to improve the application for the textbook, with the possibility of implementing these improvements in the electronic edition for the 8th grade.

To determine the factors and conditions for increasing the effectiveness of using the interactive electronic application for the “Health, Safety, and Well-being” textbook, the authors conducted an empirical study. The research sample included 600 respondents – school teachers who used the 7th-grade textbook developed by the authors during the first semester of the 2024-2025 academic year. The participants in the study represented the following regions of Ukraine: Vinnytsia (6.5%), Dnipropetrovsk (9.0%), Donetsk (6.3%), Zaporizhzhia (11.2%), Ivano-Frankivsk (8.8%), Kyiv (17.8%), Luhansk (3.8%), Odesa (11.5%), Poltava (13.2%), and Sumy (11.8%) regions. The teachers’ survey, conducted in January 2025, was anonymous, and gender differences were not considered.

To collect the necessary information, a web questionnaire was developed using Google Forms, and a quantitative research methodology was adopted, with electronic surveys serving as the primary data collection tool. The questionnaire contained closed-ended questions evaluated on a 4-point Likert scale (from 1 – strongly disagree, to 4 – strongly agree), as well as open-ended questions. Respondents also had the opportunity to justify their opinions regarding the statements proposed for evaluation.

The questions presented to the participants can be grouped into the following blocks:

- attitudes toward the availability of an electronic application to the textbook and their willingness to use it;
- advantages and disadvantages of the electronic application for the “Health, Safety, and Well-being” textbook (7th grade) developed by the authors;
- suggestions for improving the electronic

application to the textbook.

The results of the survey among school teachers regarding the effectiveness of the interactive electronic application for the integrated course “Health, Safety, and Well-being” textbook enabled the research team to design further improvements. A detailed description of the study results and conclusions is presented below.

III. RESULTS AND DISCUSSION

As we previously mentioned, the electronic educational publication developed for 7th-grade students within the integrated course “Health, Safety, and Well-being” was created by the authoring team before Ukrainian legislation officially established mandatory requirements for the use of electronic applications to textbooks and formulated clear guidelines regarding their structure and content. At the same time, a thorough review of research findings from both Ukraine and abroad, along with an in-depth study of the practical experience of using similar digital resources in education, contributed to the successful creation of a high-quality and functional application to the textbook.

Next, we will analyse the key components of this digital product, highlight its main characteristics, and explain its functional role in the educational process.

The structure of the electronic edition fully aligns with the structure of the textbook, with the number and titles of topics corresponding exactly. On the website of the Svitych publishing house (<https://svitdovkola.org/>), under the “For Students” section, each topic in the textbook is supplemented with learning materials that expand its functional and content capabilities, including:

- video and audio materials;
- online tasks;
- interactive games and various exercises created using different online resources (LearningApps, Wordwall, Livework-sheets, etc.);
- instructions and algorithms for completing tasks, as well as infographics.

These tasks are integrated into the structure of the lesson and can also be used as additional resources to diversify the forms, methods, and techniques of classroom work. Importantly, the provided materials serve as a crucial component of educational resources, and their selection depends on the teacher's level of preparation as well as the students' capabilities and competencies.

For example, for the lesson on the topic “Mine Safety”, the interactive electronic application includes the following multimedia content: a video clip on mine safety by the Ukrainian band Tanok na Maydani Kongo; an infographic of explosive hazardous objects; an online task for identifying such objects, an educational video on mine safety created by the State Emergency Service of Ukraine; an online task for detecting explosive devices; an animated film for teenagers “Enforcers – The Super Team Against Mines”; an online quest “Super Team Against Mines” by

UNICEF Ukraine (Figure 1).

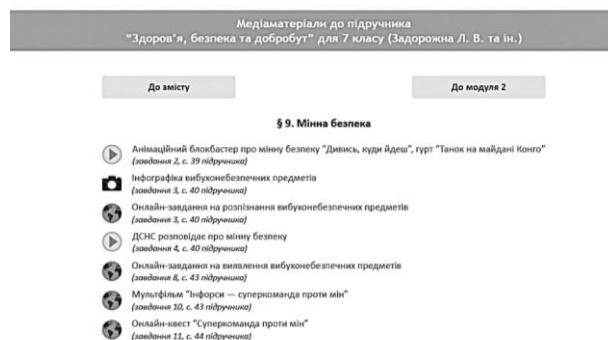


Fig 1. Multimedia content of application to §9. Mine safety.

In the printed version of the textbook, a QR code is provided at the beginning of the relevant section, directing students to this page of the e-application (Figure 2). This ensures access to these materials in an offline mode. For easier navigation within the textbook content, tasks that require using multimedia resources from the e-application are marked with a special icon.

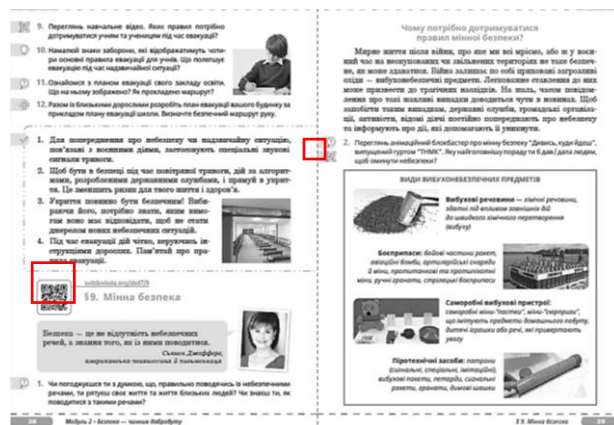


Fig. 2. Screenshot of the textbook pages with a QR code that links to the e-appendix page and an example of the rubric of the task contained therein.

We have developed tasks of varying levels of difficulty for the e-application. This allows each student to independently choose the task option they prefer to complete. Thus, the electronic application facilitates the creation of an individual learning trajectory for each student. A mandatory component of the interactive electronic application is diagnostic assessments designed to evaluate students' learning achievements during final assessments.

To support teachers in working with the textbook, the electronic application includes a “For Teachers” section. This section contains a comprehensive set of educational and methodological resources, including:

- a sample calendar-thematic lesson plan for the integrated course “Health, Safety, and Well-being”;
- lesson plans for all topics;
- printable didactic materials.

A particularly valuable resource for educators, in our opinion, is the collection of lesson plans for textbook topics (Figure 3). In addition to the content presented in the textbook, these lesson plans include supplementary materials aimed at deepening the topic. Given teachers' pedagogical autonomy in selecting methodological tools, these materials can be used in a modular approach. That is, depending on the content of the textbook section, its depth, and the number of hours allocated for its study, a teacher can use any task independently or as a component for effectively delivering the lesson content.

Розробки уроків за темами навчальної програми

Модуль 1	Основи доброчину. Уміння вчитися
Модуль 2	Безпека — чинник доброчину
Модуль 3	Турбота про здоров'я. Розділ 1
Діагностувальна робота №1	
Модуль 3	Турбота про здоров'я. Розділ 2
Модуль 4	Підприємливість і фінансова грамотність
Модуль 5	Спілпраця для доброчину. Волонтерство
Діагностувальна робота №2	

Fig. 3. Development of lessons on the topics of the curriculum as a component of the e-appendix to the textbook.

In addition to lesson plans for traditional in-person instruction, the e-application also includes plans for distance-learning lessons.

A survey conducted among teachers from Ukrainian general secondary education institutions (Figure 4) showed that the majority of teachers (508 respondents – 84.7%) hold a completely positive attitude toward electronic applications for textbooks, have experience using them in lessons, and are willing to continue integrating them into their teaching practice. Furthermore, 467 respondents (77.8%) noted that the availability of an electronic supplement was the decisive factor in choosing our textbook for their work. However, 68 teachers (11.3%) expressed a generally positive attitude but mentioned difficulties in adapting to using e-applications in lessons due to the lack of digital devices among all students in their classrooms and school-wide internet access issues. Only 24 respondents (4.0%) had a negative view of e-applications, considering them as mere entertainment elements. These teachers believe that mobile phones should be banned in schools as they only distract students from the learning process.

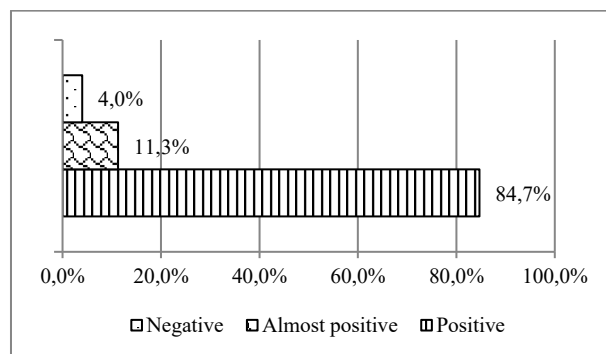


Fig. 4. Attitude of teachers to the electronic application of the textbook.

Analysis and interpretation of the collected research data allowed us to summarize the key strengths of the electronic supplement to the textbook as highlighted by practicing teachers. The obtained results are presented in Table 1.

The drawbacks highlighted by a few participants in our survey were mostly of a recommendatory nature. For example:

Respondent 36: There are no critical shortcomings. However, not all digital tools are available in sufficient quantity.

Respondent 434: It would be helpful to provide a more detailed guide on how to use some multimedia applications.

Respondent 523: The textbook contains excellent multimedia applications, but the authors should consider adding a library of online services so that teachers can create digital content independently.

TABLE 1 ADVANTAGES OF THE ELECTRONIC APPLICATION TO THE "HEALTH, SAFETY, AND WELL-BEING" TEXTBOOK (7TH GRADE))

Positive features of the e-application	Percentage of respondents who emphasized this
Increases students' motivation to learn	83,5%
Enhances students' cognitive engagement	91,2%
Expands the use of interactive learning methods	81,0%
Supports personalized learning pathways	72,0%
Enables formative assessment and self-evaluation through instant feedback	68,5%
Develops digital competence in both teachers and students	65,7%
Allows the inclusion of students' real-life experiences	86,8%
Improves the effectiveness of blended learning	84,2%
Helps develop teamwork skills	83,2%
Encourages parental involvement in the educational process	56,2%

Before creating the electronic supplement for the "Health, Safety, and Well-being" textbook for the 8th grade, the authors greatly valued teachers' practical

suggestions for its improvement. To gather these insights, we included an open-ended question in our survey. Unfortunately, the majority of respondents (90.7%) simply reiterated their positive feedback on the 7th-grade e-application and expressed a desire to receive similar content adapted to students' age-related changes. Some responses (1.3% of respondents) identified the lack of correct answers for online tasks as a drawback.

Among the most significant improvement suggestions provided by survey participants were:

- adding a separate "Remote Lessons" section;
- diversifying the multimedia content;
- increasing the number of infographics;
- including informational reference materials within studied topics;
- adding self-assessment tasks for students;
- expanding the educational and methodological resource set, incorporating a student workbook and teacher's practical task guidelines.

IV. CONCLUSIONS

The experimental study allowed us to analyse the main advantages and disadvantages of the electronic application for the "Health, Safety, and Well-being" textbook (7th grade). The feedback received enabled us to refine the electronic edition, improve its content and structure, and consider teachers' recommendations when developing the 8th-grade e-application. Specifically:

- diversified the multimedia content by adding presentations and animated videos.
- increased the number of visual elements, particularly infographics.
- to deepen individual topics and support differentiated learning, we added reference materials with extra information beyond the curriculum.
- to develop students' reflective skills, self-assessment tasks were included for every lesson.
- for teachers' convenience, remote lessons were placed in a separate section.
- the educational-methodological complex was expanded with teacher guidelines for practical tasks and a student workbook.

We believe these enhancements will improve the content and structure of the interactive electronic application, increase its functionality, and ultimately enhance its effectiveness in helping students master the model curriculum and achieve the required learning outcomes.

Our work on improving the e-application does not end here. We are exploring the possibility of integrating online services and programs into the supplement, enabling students to create their own digital products individually

and collaboratively. The results of this work will be presented in our future research.

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Multimedia Technologies in the Training of Students of Higher Education Institutions in Ukraine for Animation Activities in the Recreation and Wellness Sector

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Abstract— This article examines the development of animation competencies among future tourism professionals in the recreational and wellness sector through the implementation of multimedia technologies. A theoretical model was developed and empirically validated to enhance professional training efficiency through computer-based tools. The research emphasizes the role of interactive presentations, video content, virtual and augmented reality applications, and specialized software in the educational process.

The study surveyed 330 students from Ukrainian higher education institutions regarding multimedia technology integration in tourism education. Results demonstrated that students most effectively acquired skills in designing animation programs incorporating health fitness components (46.55%) and sports activities (45.12%), while showing lower proficiency in organizing sports animation and wellness centre activities (22.14%).

A survey of 72 higher education instructors revealed varying pedagogical approaches: 39.57% prioritize

preparation for animation activities in recreation and wellness; 46.05% implement regular computer-based assessments; 41.72% utilize business simulations; 41.41% conduct master classes; and 48.75% organize quest-based learning activities. The data indicated that 16.79% of instructors emphasize fitness and wellness animation programming, while only 4.67% focus on entertainment-based animation. Furthermore, 48.65% evaluate animation competencies through event organization (competitions, performances, festivals, carnivals, and theatrical productions); 33.82% prioritize experience in music-based animation programs; and 57.66% advocate for practical training in various professional settings, including hotel and restaurant complexes, wellness centres, sanatoriums, children's camps, resorts, and transportation facilities.

The findings suggest that multimedia technology integration enhances creativity, communication skills, and collaborative abilities—competencies essential for animation activities in tourism. This research demonstrates that incorporating digital tools into tourism education effectively

Online ISSN 2256-070X

<https://doi.org/10.17770/etr2025vol3.8516>

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addresses contemporary tourism industry demands and professional requirements.

Keywords – *animation, multimedia technologies; recreation, students, tourism.*

I. INTRODUCTION

The alignment of tourism education with international standards is a crucial prerequisite for Ukraine's integration into European and global educational space. Higher education institutions are therefore developing innovative approaches to train competent tourism professionals capable of addressing complex challenges in the recreational and wellness sector. This evolution in tourism education reflects the growing importance of professionals who can effectively implement diverse forms of physical activity to promote active recreation and healthy lifestyle choices among tourism service consumers.

Recent scholarly literature demonstrates significant research attention from both national and international academics regarding the professional development of prospective tourism specialists in animation activities within the recreational and wellness sector, reflecting current paradigms in higher education. The existing research encompasses multiple dimensions, including the implementation of animation activities across diverse contexts [1], as well as the cultivation of professional competencies among future tourism specialists in event conceptualization and execution [2, 3, 4].

Researchers indicate that the readiness of prospective tourism specialists for animation activities in the recreational and wellness sector comprises several structural components such as [2]:

Motivational Component. It encompasses intrinsic motivation for self-development and skill enhancement, along with the evolution of existing motives and formation of new ones during professional training. This component is activated through needs, value orientations, and behavioural factors that influence future specialists' engagement in animation activities.

Intellectual Component. It involves comprehensive knowledge of developing and implementing diverse animation service programs targeted at specific demographic groups.

Activity-Based Component. It demonstrates the capacity to utilize various forms of physical activity in designing active recreation programs across accommodation and wellness facilities, adapted for different population segments.

Communicative-Productive Component. It is characterized by an approachable communication style, commitment to continuous improvement, and the ability to maintain constructive dialogue and effective interaction with tourism service consumers.

Reflective Component. It encompasses conscious self-assessment of professional achievements, identification of promising areas for career development, capability to

evaluate behavioural patterns of diverse population segments, and professional self-actualization.

M. Danylevych [5] argues that implementing a competency-based approach in higher education facilitates the systematic development of professional competencies, enabling graduates to function effectively within contemporary multidimensional environments characterized by complex socio-political dynamics, market-driven economics, and intensive information-communication flows.

Researches conducted by A. Kolesnik and A. Tarasov [6] and A. Manako [7] examining diverse applications of multimedia content in education demonstrate that such technologies enhance both learning outcomes and foster students' critical thinking and creativity. This finding is particularly significant for animation activities, which demand not only theoretical knowledge but also adaptive competencies and innovative problem-solving skills in dynamic environments.

L. Zanevska [8] posits that the integration of information technologies in physical education specialist training constitutes an essential prerequisite for developing professional competencies. This observation holds particular relevance for animation specialists, who must demonstrate versatility in diverse operational contexts and exhibit adaptability when engaging with heterogeneous audience demographics.

Thus, the relevance of this study stems from several factors: society's demand for specialists capable of effectively implementing animation activities in the recreational and wellness sector; the necessity to develop educational and methodological support for preparing future tourism specialists in animation activities; and the significant potential of animation activities in the recreational and wellness sector as a promising direction for attracting consumers to recreation and health promotion services.

The aim of this study is to theoretically substantiate and empirically verify the organizational and pedagogical conditions necessary for preparing future tourism specialists for animation activities in the recreational and wellness sector.

II. MATERIALS AND METHODS

The research methodology incorporated multiple approaches: analysis, content analysis, abstraction, retrospective analysis of personal scientific and pedagogical experience in higher education; structural and systemic analysis; modelling and design; generalization and synthesis; questionnaires, testing, and pedagogical experimentation; methods of mathematical statistics.

The study sample comprised 330 second-year students pursuing a degree in Tourism (Specialty 242) and 72

academic staff members from five Ukrainian higher education institutions (HEIs).

The formative experiment involved 112 students from the Classic Private University, Ivan Bobersky Lviv State University of Physical Culture, and Yuriy Fedkovych Chernivtsi National University. Participants were divided into control (CG, n=55) and experimental (EG, n=57) groups. These groups were homogeneous in both quantitative and qualitative characteristics at the experiment's onset. While the CG followed the traditional educational system, the EG underwent training incorporating the theoretically substantiated organizational and pedagogical conditions for developing animation activity competencies in the recreational and wellness sector.

III. RESULTS AND DISCUSSION

Enhancing the professional training system for tourism specialists in animation activities requires extensive implementation of innovative educational technologies. The proposed model for developing animation activity competencies comprises five interconnected and mutually dependent subsystems: target, theoretical-methodological, content, procedural, and evaluative (Fig. 1).

The procedural subsystem encompasses forms, methods, means, stages, and functions of competency development. The forms include lectures, practical and seminar sessions in courses such as "Tourism Organization (Animation Technologies)", "Sports Animation Organization", "Dance Animation Organization", educational conferences, consultations, and industrial internships.

The methods are categorized into two groups: simulation (business and role-playing games, training sessions) and non-simulation (problem-based lectures, discussions, round tables with leading tourism experts, brainstorming sessions, and multimedia presentation development).

The educational means include textbooks, assessment tools; ICT resources (multimedia technologies, electronic libraries, Moodle and Zoom platforms); animation tools (physical exercises, team-building activities, dance programs, relay races, orienteering elements, obstacle courses, quizzes); and recreational tools (recreational and sports games, entertainment activities, physical activities, hiking trips).

The practice-oriented stage of developing professional competency in animation activities among future tourism specialists in the recreational and wellness sector encompassed students' acquisition of knowledge, skills, and competencies necessary for their future professional practice. This was implemented through courses such as "Sports Animation Organization", "Dance Animation Organization", and "Tourism Organization (Animation Technologies)". To evaluate this stage, a student

questionnaire was conducted.

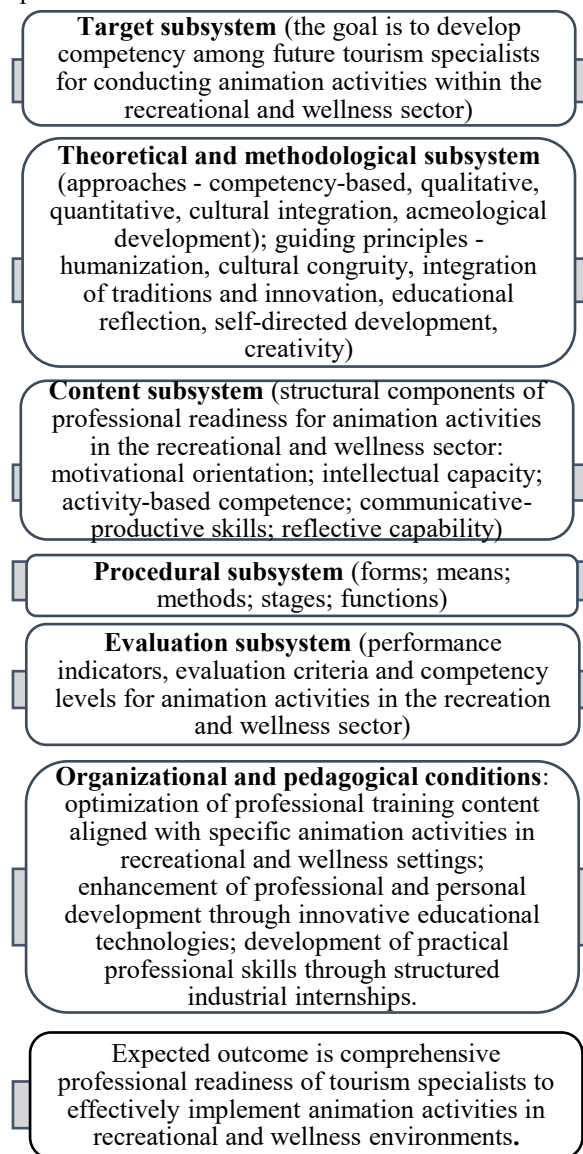


Fig.1. General Framework of the Model for Developing Professional Competency in Animation Activities among Future Tourism Specialists in the Recreational and Wellness Sector.

The questionnaire results indicate that future specialists most successfully acquired skills in: developing animation programs incorporating wellness fitness elements (46.55%) and sports games (45.12%); organizing and implementing sports animation activities in leisure and rehabilitation centres (22.14%). However, the analysis revealed insufficient mastery of skills in designing and conducting animation programs across various contexts, including hotel and restaurant complexes, sports and wellness facilities, sanatoriums, children's recreational camps, leisure centres, and during transportation. These findings from the student respondents indicate the necessity for modifications and adjustments to the current training system for future tourism specialists in animation

activities within the recreational and wellness sector.

To ensure appropriate facilitation of professional and personal development of future tourism specialists through innovative educational technologies, a questionnaire of academic staff was conducted. This research is particularly relevant as Ukraine's higher education system has recently undergone diversification in teaching methodologies for professional training.

The questionnaire of 72 academic staff members from Ukrainian higher education institutions revealed the following findings: 39.57% of respondents focus their efforts on developing students' competency in animation activities within the recreational and wellness sector; 46.05% regularly implement computer-based testing for student assessment; 41.72% utilize business simulations; 41.41% conduct masterclasses; 48.75% incorporate quest-based learning activities.

Regarding specific animation program focus: 16.79% emphasize physical education and wellness animation programs. Only 4.67% concentrate on entertainment-based animation programs.

In terms of practical skill development: 48.65% direct their efforts toward organizing and conducting various events (competitions, demonstrations, festivals, carnivals, and cultural-historical theatrical performances) to assess students' animation activity competencies; 33.82% focus on students' acquisition of experience in organizing and conducting music-accompanied animation programs; 57.66% consider it beneficial to conduct industrial internships in various settings: hotel and restaurant complexes, sports and wellness facilities, sanatoriums, children's recreational camps, leisure centres, transportation-based activities during trips.

The development of comprehensive test packages for professionally-oriented courses, specifically "Tourism Organization (Animation Technologies)", "Sports Animation Organization", and "Dance Animation Organization", enabled student knowledge assessment during classroom sessions through the Moodle multimedia platform. Currently, higher education institutions in Ukraine are necessitated to implement distance learning formats, facilitating the adoption of new teaching technologies.

A. Zakharina, in collaboration with L. Sushchenko and I. Koloshchuk, developed a computer program "Pedagogical Diagnostics of Professional Readiness Among Future Tourism Specialists for Animation Activities in the Recreational and Wellness Sector" for evaluating competency levels of future tourism specialists in animation activities within the recreational and wellness sector. This diagnostic tool is designed to accommodate student group testing for up to 130 participants. Algorithm for the programme application is presented in Fig. 2.

The empirical validation of the proposed pedagogical model demonstrates its efficacy in developing animation competencies among prospective tourism specialists. The

implementation of this model, incorporating computer-based assessment methodology, yielded statistically significant outcomes in competency development metrics.

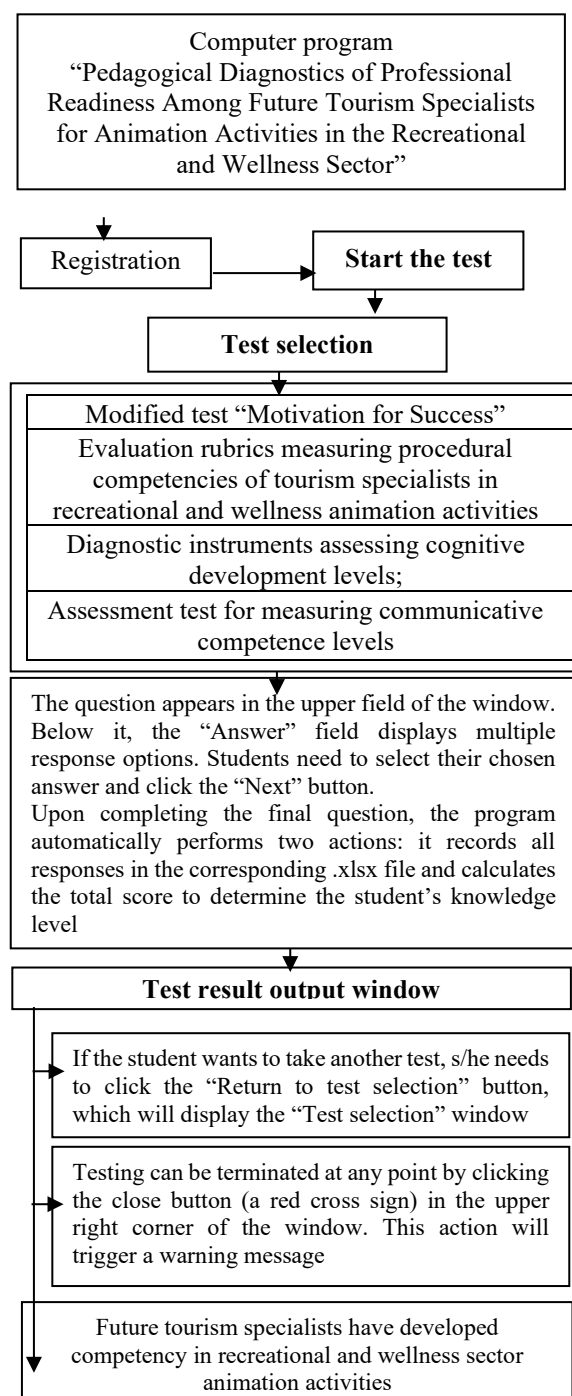


Fig. 2. Algorithm for using the computer program.

Comparative analysis between the EG and CG revealed distinctive patterns in competency acquisition. The EG students exhibited substantial positive trajectories across all competency levels. Specifically, the proportion of participants demonstrating high-level competencies increased by 11.23 percentage points (from 8.77% to

20.00%), while those with intermediate competencies showed a 13.67 percentage point increase (from 47.73% to 61.40%).

Correspondingly, the percentage of participants exhibiting low-level competencies decreased significantly by 25.26 percentage points (from 43.86% to 18.60%).

In contrast, the CG students demonstrated marginal progression. The proportion of participants with high-level competencies increased by 5.46 percentage points (from 9.09% to 14.55%), while intermediate competencies showed an 8.72 percentage point increase (from 39.64% to 48.36%). The reduction in low-level competencies was less pronounced, with a 14.18 percentage point decrease (from 51.27% to 37.09%).

These quantitative indicators (Table 1) substantiate the enhanced efficacy of the proposed pedagogical model in developing animation competencies for recreational and wellness sector applications.

TABLE 1
 DYNAMICS OF THE LEVELS OF READINESS OF THE CG AND EG STUDENTS FOR ANIMATION ACTIVITIES IN THE RECREATIONAL AND WELLNESS SECTOR (N=112)

Level	Groups	Results of the pedagogical experiment				
		Before		After		Differences in %
		Number of people	in %	Number of people	in %	
High	EG (n=55)	5	9,09	8	14,55	5,45
	CG (n=57)	5	8,77	11	20,00	11,23
Intermediate	EG (n=55)	22	39,64	27	48,36	8,73
	CG (n=57)	27	47,37	35	61,40	14,04
Low	EG (n=55)	28	51,27	20	37,09	14,18
	CG (n=57)	25	43,86	11	18,60	25,26

In general, within the structure of components of future tourism professionals' readiness for animation activities in the recreational and wellness sphere, significant differences were established between the readiness levels of students in the experimental group (EG) (208.20 ± 4.02 points) and those in the control group (CG) (186.73 ± 3.94 points) (with $t_{calc}=3.80$). The summarized data are presented in Table 2.

TABLE 2
 READINESS INDICATORS OF STUDENTS IN EG AND CG FOR ANIMATION ACTIVITIES IN THE RECREATIONAL AND WELLNESS SPHERE, POINTS

Results of the pedagogical experiment	Group	M ± m	σ	t _{calc.}	t _{table}
Before	EG (n=55)	177.38 ± 4.09	30.34	0.87	1.99
	CG (n=57)	182.49 ± 4.18	31.54		
After	EG (n=55)	208.20 ± 4.02	30.37	3.80	1.99
	CG (n=57)	186.73 ± 3.94	29.37		

The empirical findings derived from the experiment demonstrate the efficacy of the identified and theoretically substantiated organizational and pedagogical frameworks for developing future tourism specialists' competency in animation activities within the recreational and wellness sector.

The integration of innovative technologies into the educational curriculum has significantly enhanced the professional and personal development of future tourism specialists. Specifically, it has facilitated: the development of critical thinking skills; the enhancement of professional knowledge acquisition; the formation of profession-oriented cognitive processes; the stimulation of research activities; and the expansion of both self-assessment capabilities and systematic evaluation through the computer-based program "Pedagogical Assessment of Professional Readiness Among Future Tourism Specialists for Animation Activities in the Recreational and Wellness Sector".

The preparation of future tourism specialists for animation activities in the recreational and wellness sector has acquired particular significance in contemporary conditions. The findings of this investigation both corroborate and expand upon previously established aspects of this domain. A substantial body of researchers [9-13] has investigated the impact of modern multimedia technologies on educational processes, demonstrating their capacity to create more engaging and interactive learning environments. Our research confirms that the implementation of multimedia technologies enhances student engagement and facilitates more effective knowledge retention.

Multimedia resources contribute significantly to developing students' health consciousness, a central theme in the research conducted by I. Hrybovska et al. [14]. The pedagogical methodologies outlined in their study can be effectively adapted for multimedia-based animator training. The synthesis of these research findings enables the development of a comprehensive learning approach, integrating physical education, health awareness, and

contemporary technologies. This integration can serve as a foundation for developing innovative programs that address student needs within modern educational frameworks. Additionally, the multimedia tools described in studies [15,16] can be effectively utilized in creating educational materials, presentations, and interactive sessions in recreational animation, as evidenced by our findings.

The examination of multimedia technologies' influence on education and animation activities has garnered significant attention from international researchers, providing broader insights into global trends. S. Göksu and M. Kocakaya's research [17] investigates the correlation between multimedia materials and student achievement. Their findings indicate that multimedia resources not only enhance academic performance but also positively influence students' learning attitudes — a crucial factor in animator training, as positive learning dispositions contribute to more effective professional development. Studies [18-21] further demonstrate the beneficial impact of integrating multimedia resources into physical education institutions, aligning with our conclusions regarding the significance of multimedia technologies in animation activity preparation.

Given that contemporary animation activities necessitate proficiency in digital tools, the role of multimedia technologies in developing digital literacy and overall educational outcomes has become increasingly prominent. Our findings align with numerous scholars [22-25] who emphasize the crucial role of multimedia technologies in preparing students for animation activities. Our study also confirms the findings of scientific research on the important role of recreational and wellness activities in the learning process of students and in improving their quality of life [26, 27]. This underscores the necessity for continued development and implementation of innovative technologies within educational curricula to enhance the quality of education in Ukraine.

IV CONCLUSIONS

The conducted pedagogical experiment conclusively demonstrates the effectiveness of the identified and theoretically substantiated organizational and pedagogical conditions in developing future tourism specialists' competency in animation activities within the recreational and wellness sector. The EG students exhibited significantly higher levels of preparedness for animation activities compared to the CG students. The implementation of multimedia technologies fostered the development of creative capabilities, communication proficiency, and collaborative skills—essential competencies for successful animation activities in tourism. Consequently, the integration of digital tools into the educational process enables the adaptation of

professional training to meet contemporary challenges in the tourism industry.

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Integrating History and Software Engineering: A STEM-Based Approach to Teaching

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Abstract- The interdisciplinary approach is an effective method in technical education, particularly for integrating humanitarian disciplines with specialised subjects. However, history, philosophy, Ukrainian, and foreign languages often receive minimal teaching hours, leading to insufficient mastery. To address this, we explored the integration of history and culture with technical disciplines, specifically "Modern Programming Paradigms" and "Methods and Systems of Artificial Intelligence," to enhance learning for future software engineers. A STEM project was implemented to explore Ukrainian statehood through engineering solutions and modern technologies. First-year Computer Science students engaged with interactive digital tools, including low-code web application frameworks (Glitch, WordPress), historical data visualisation (Flourish), timeline and mapping tools (TimelineJS, StoryMapJS), and interactive presentations (Canva, Google Slides). The project's effectiveness was assessed using a rubric-based evaluation with three key criteria: content, technology, and collaboration. The analysis showed no statistically significant differences between teams ($p > 0.05$), indicating consistent engagement. The highest score was in "Collaboration" (3.47), demonstrating effective teamwork. The "Technology" criterion (3.23) reflected satisfactory proficiency in software tools, while "Content" scored the lowest (2.73), highlighting challenges in integrating historical narratives with programming. Correlation analysis showed a weak

relationship between criteria, meaning technical skills did not necessarily translate into high-quality content or teamwork. A SWOT analysis based on an anonymous student survey provided direct feedback for improving future STEM projects. Key advantages included deeper assimilation of historical facts, practical application of programming skills, and teamwork experience. However, students noted limited time for mastering content and a lack of necessary equipment as challenges. These findings highlight the need to strengthen the historical component and improve programming integration with humanities for a more comprehensive learning experience.

Keywords- Computer Sciences, History of statehood and culture, Software Engineers, STEM Projects, Programming

I. INTRODUCTION

Until recently, Ukraine has been experiencing a trend towards reducing the number of subjects in the humanities cycle in non-humanities institutions. Some scholars have even suggested eliminating the history course from curricula, arguing that this is due to the similarity of topics and the sequence of presentation of the material, as well as new requirements for a modern engineer. However, such approaches do not consider the specifics of teaching history in higher education institutions, which should be carried out problem-based [1] with the

Online ISSN 2256-070X

<https://doi.org/10.17770/etr2025vol3.8557>

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obligatory adaptation of the course of history and culture of the country to the specialization of students.

The development of science and technology will determine humanity's general progress [2]. At the same time, a critical factor for the economies of developed countries is the contradiction between the constantly growing shortage of specialists in high-tech industries and the decline in student's interest in natural and mathematical sciences [3].

To become a competitive IT engineer, an extraordinary training trajectory should be developed for students in technical specialties. One of the components of such training should be the integration of unique disciplines of the IT industry with subjects of artistic direction, in particular, courses on art history, design theory, graphic arts, etc. Such integration will contribute to developing social and personal competencies [4].

An interdisciplinary approach creates "bridges" between different branches of knowledge, contributing to the enrichment of methodological tools and the formation of new scientific knowledge [5], [6]. In particular, integrating humanitarian and technical disciplines allows future engineers to acquire a wide range of knowledge and skills. The profession of a software engineer, according to the four-level classification of occupations, combines the types of "man-technician", "man-human", and "man-sign systems". This requires a specialist with technical competencies, a broad outlook, and knowledge of the humanities (philosophy, psychology, management).

Literature review.

Scientists emphasize that forming complex competencies in a modern software engineer is impossible without including humanitarian disciplines in the educational process [7]. Among the effective methods for developing the professional culture of software students, it is worth noting that professional discussions contribute to the formation of critical thinking and communication skills [8].

Researchers also emphasize the feasibility of integrating a foreign language with specialized disciplines during the training of future programmers [7], [9].

A literature review indicates limited experimental studies devoted to integrating history and STEM disciplines, particularly in the interaction between teachers of different subjects [10]. History is often perceived as a discipline focused on the past, while engineering is focused on the future, which creates specific barriers to integration. However, studies demonstrate the potential benefits of such a combination for developing critical thinking and a deeper understanding of the subjects.

For example, Park and Song [11] examined the possibilities of studying the history of science using ancient Chinese mathematical texts. Another study showed the successful reconstruction of Charles Page's electromagnetic motor as part of an interdisciplinary project for K-12 students [12].

These examples demonstrate that integrating history with STEM subjects deepens subject knowledge and stimulates students to think creatively and find unconventional solutions.

The paper aims to investigate the effectiveness of the integration of such disciplines as history and programming through projects with students majoring in Computer

Sciences. The research focuses on examining central software engineers' competencies in the multidisciplinary context, assessing the impact of projects in acquiring knowledge in Ukrainian state-building, and determining strong and weak options for STEM projects through SWOT analysis. The ultimate goal of the study is to identify ways to optimise STEM projects in non-humanitarian higher education institutions.

II. MATERIALS AND METHODS

A group of historians and a lecturer from the Department of Digital, Educational and Socio-Economic Technologies created a project called "Interactive Chronology of Ukrainian Statehood". The STEM project aimed to teach future IT specialists to analyze historical events, think critically and visualize them in the form of technological solutions; develop programming skills using tools and technologies to create an application interface; visualize historical data in the form of graphs and charts, as well as work together on the project.

The experiment was conducted at the Kamianets-Podilskyi State Institute with 1st-year bachelor's students majoring in Computer Science. Students from two groups (n=30) were divided into five teams. Classes were held weekly during the 1st semester of the 2024 academic year as part of the Statehood and Culture Studio.

The article used quantitative and qualitative methods of analysis. ANOVA analysis of variance was used to determine statistically significant differences between teams according to the rubrics. Correlation analysis was used to identify the presence or absence of a relationship between the evaluation criteria. Average scores were also calculated to diagnose the success of students' projects. Anonymous student questionnaires and SWOT analysis were used as qualitative methods of analysis.

III. RESULTS AND DISCUSSION

Students were to research the following stages of Ukrainian statehood: Kyiv Rus, Hetmanate, UNR, and independent Ukraine, focusing on historical events, figures, and key dates. Next, work continued to create a web application. Given the initial level of digital competencies, students used simple technologies. Flourish was used to visualize historical events, and TimelineJS and StoryMapJS were used to depict a particular period visually. Students were invited to use Canva or Google Slides to create interactive presentations.

The project defence took place in the form of an application demonstration. The STEM project was evaluated in three categories: Content, Technology, and Collaboration on a scale of 1 to 5. History teachers evaluated the first category, the second by a programming teacher, and the third by all teachers.

The following statistical data processing methods were used to analyze the results of the STEM project: calculation of average scores for each rubric for each team, as well as analysis of variance (ANOVA) to determine statistically significant differences between teams. The average scores for each team are given in (1).

TABLE 1 DISTRIBUTION OF POINTS FOR EACH CATEGORY

Team	Content	Technology	Collaboration
Team 1	4.00	3.83	3.33
Team 2	2.17	3.67	3.17
Team 3	2.67	3.50	3.00
Team 4	2.50	2.33	4.00
Team 5	2.33	2.83	3.83
Total	2.73	3.23	3.47

The overall average scores for the three criteria for all teams showed that the lowest average score was obtained in the "Content" category (2.73). This indicates a superficial and insufficiently deep study of the material on the history of statehood and culture. In contrast, the average scores in the "Technology" category (3.23) demonstrate sufficient technical skills for implementing STEM projects. The highest average score (3.47) was recorded in the "Collaboration" category, which indicates effective teamwork, successful communication, and joint decision-making during the implementation of the STEM project.

To assess the differences in task performance between teams, analysis of variance (ANOVA) was used according to the specified criteria (Fig.1).

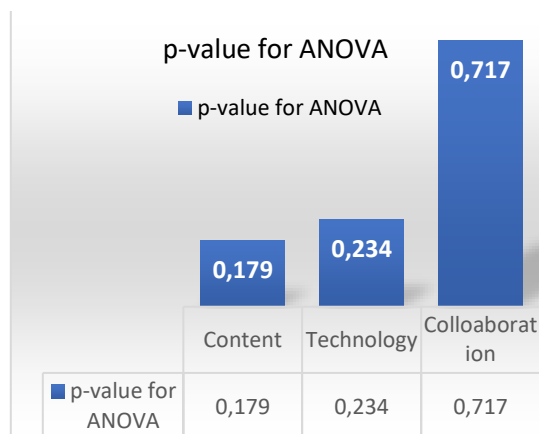


Fig. 1. Graphical presentation of the results of analysis of variance (ANOVA) according to the specified criteria

In the "Content" category, the p -value is 0.179. Since the p -value ≥ 0.05 , there are no statistically significant differences between the achievements of the teams.

The analysis of variance for the "Technology" category also did not reveal significant differences (p -value = 0.234), which indicates the same level of mastery of modern technologies among students.

The highest p -value (0.717) was recorded in the "Collaboration" category, which confirms the uniformity of teamwork and effective communication in all teams.

The absence of statistically significant differences between teams indicates an even distribution of knowledge among students and the effectiveness of the teaching methodology.

To conduct a SWOT analysis of the STEM project, an anonymous survey of students was organized, which included the following questions:

- What aspects of the project did they like the most (with the ability to select multiple options)?
- How did the project affect the understanding of historical topics?
- What difficulties did the respondents encounter?

The survey results formed the basis of the SWOT analysis, the results of which are shown in Table 2.

TABLE 2 THE SURVEY RESULTS FORMED THE BASIS OF THE SWOT ANALYSIS

STRENGTHS	WEAKNESSES
Developing teamwork and communication skills. Improving programming skills and working with modern technologies. Contributes to a deeper understanding of Ukrainian state-building and culture.	Lack of time for in-depth study of the topic can lead to a superficial perception of the material. Lack of access to necessary equipment may hinder effective project implementation. Uneven workload among team members.
OPPORTUNITIES	THREATS
Using successful elements of the project to develop new courses and programs. Possibility of involving experts in history and programming to conduct master classes and seminars	Frequent technology updates can necessitate rapid professional development for students and faculty. Internal conflicts within a group can negatively affect the learning atmosphere.

The combination of humanitarian and technical knowledge within the STEM project primarily contributed to developing teamwork and effective communication, key skills for future IT engineers. While working on the project, students could apply their programming skills in practice to create a web application, which allowed them to combine theoretical knowledge with real technological solutions.

The SWOT analysis showed that the successful elements of the project can be integrated into new courses and curricula. At the same time, the initial goal was to significantly deepen students' knowledge of the history of statehood and culture of Ukraine. However, the results indicate that the best indicators were achieved in developing teamwork and using modern technologies.

Among the identified weaknesses of the project is the limited time for completing tasks, which led to a superficial study of historical material. Given this, it would be advisable to plan similar STEM projects in the second semester when students already have basic knowledge of history. An alternative option could be to focus on one historical period, for example, the Hetmanate or the Ukrainian People's Republic, for independent study. This will help develop search skills and foster research interest.

IV. CONCLUSIONS

The STEM project, created based on the interdisciplinary interaction of the courses "History of Statehood and Culture" and "Modern Programming Paradigms and Methods of Artificial Intelligence", demonstrated success in developing teamwork, effective communication, and collective decision-making - key skills for future IT specialists. Students confidently applied their technical competencies to create a web application, confirming achieving goals in the programming field.

However, the content component of the project turned out to be less developed, which indicates the need to adjust the methodology for a deeper assimilation of historical material.

To improve the content of the project, it is necessary to:

1. Review of the project structure

- Increase the time needed to process historical material before starting work on the technical part.
- Transfer the implementation of the project to the second semester of the first year so that students have basic knowledge of history.
- Distribute historical periods between teams for a deeper analysis of individual stages: Team 1 — Kyiv Rus, Team 2 — Hetmanate, Team 3 — UNR, Team 4 — Independent Ukraine.

2. Involvement of specialists and interactive methods:

- Organize consultations, seminars and guest lectures with the participation of expert historians.
- Use the opportunities of university history clubs to conduct quests, debates and thematic studies.
- Involve students in analyzing sources and creating interactive visualizations (for example, chronological maps or timelines).

3. Adjustment of the assessment system:

- Increase the weight of the assessment for the "Content" category in the overall result to stimulate a deeper study of the material.

- Introduce intermediate control - mandatory stages of assessment before moving on to the technical part.
- Use self-assessment and mutual assessment elements to determine each participant's contribution to studying historical topics.

The STEM project demonstrated high effectiveness in developing team and technical skills; however, it is necessary to improve the methodology for mastering the content part to balance the humanitarian and technical components. The proposed adjustments will improve the results in the "Content" category and increase the overall quality of the project, creating conditions for integrated learning and the development of critical thinking.

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AI for Enhancing English Lesson Design and Pedagogy in Chinese Middle Schools

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Abstract — AI-empowered English lesson design and pedagogy is potentially reconstructing educational practices in middle schools in China. While AI was previously infrequently used in the field of curriculum design, the introduction of tools like Deep Seek have ignited a wave of major innovation. The literature review distills insights from 70 empirical and theoretical studies to identify trends in AI-driven personalized learning, adaptive assessment, and novel instructional design. English teachers are one of education's greatest change agents for decades who are using Deep Seek in tandem with multimedia authoring tools for creating dynamic and engaging lessons. Many private schools, especially in Sichuan province, have also started to use "AI-assisted learning" models, and educational bureaus and large-scale competitions have further encouraged this new development. However, challenges like misalignment with curriculum, ethical problems, and the need for teacher professional development continue. Policy recommendations include adopting a future orientation and promoting training.

Keywords- AI, Chinese middle school , Deep Seek, personalized education

I. INTRODUCTION

AI has revolutionized many industries and is becoming ever more prevalent in education. Innovative AI tools have been challenging traditional English lesson design methods in Chinese middle schools. While AI application in classrooms had previously been limited, recent developments, such as Deep Seek integrated desktop system have enabled teachers to generate dynamic instructional materials by the use of auto-updated PPT tools, multimedia editors, and audio-visual integration. English as a subject that led the way in educational reform, and now teachers are experimenting with AI-driven instruction that speaks to 21st-century learners in a deep and meaningful way. This review summarizes findings across 70 articles and identifies trends in AI-enabled personalized learning, adaptive assessments, and collaboration between teachers and AI,

emphasizing the trans-formative implications of these technologies for the delivery of English language lessons in China [1],[2].

II. MATERIALS AND METHODS

A systematic literature search was carried out by exploring multiple academic databases (Web of Science, ERIC, and IEEE Explore) for studies published from 2010 to 2024. Inclusion criteria included empirical and theoretical studies addressing the incorporation of artificial intelligence into educational systems, especially within secondary schools teaching the English language. Related studies on AI-supported lesson design, personalized learning, and teacher - AI collaboration were selected (n = 70). Qualitative thematic analysis was used alongside quantitative bibliometric techniques to ascertain key trends and challenges. The main categories drawn from the research include AI-facilitated curriculum design by the use of such tools as Deep Seek applications, instructor readiness and professional training, AI-powered evaluation schemes, and ethical and infrastructural concerns. Data were manually coded, and results were narratively synthesized to reflect the evolving nature of AI-enhanced pedagogy in both Chinese and international contexts.

III. RESULTS AND DISCUSSION

A. Global and Chinese Applications of AI in English Teaching

The use of Artificial Intelligence for English language teaching (ELT) is on the rise globally, with the emergence of intelligent tutoring systems, automated assessment tools, and generative language models [3], [4]. In Western contexts, AI is mostly applied for providing formative feedback, improving writing skills,

Online ISSN 2256-070X

<https://doi.org/10.17770/etr2025vol3.8562>

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and customized grammar practice [5], [6]. In China, the rapid adoption of AI in education has been driven by national policies, especially after the introduction of the “Smart Education of China” initiative in 2021. English teaching has become a testing ground for AI tools such as automated essay scoring systems, speech recognition, and pronunciation correction software [7], [5]. However, uptake at scale remains uneven. AI-augmented programs are more often developed in urban schools as opposed to rural ones, where infrastructure is limited. Government pilot programs tend to start in well-resourced private or model schools, which also have better teacher development support. The recent arrival of Deep Seek has made AI lesson planning more approachable. For example, in provinces such as Sichuan, schools are piloting AI as a “companion teacher” during writing instruction, speaking practice, and feedback on assessments. These trends represent the beginnings of a pedagogical shift but are stymied by issues of access, teacher training, and evaluation infrastructure. These trends are summarized in Table 1 below.

Table 1 provides a broad overview comparing global and Chinese perspectives on AI-supported English teaching. To further illustrate these comparisons in greater detail and highlight specific insights from multiple researchers, Table 2 offers a thematic breakdown emphasizing various authors' viewpoints on key aspects of AI integration.

TABLE 1. COMPARISON OF GLOBAL VS. CHINESE PERSPECTIVES ON AI-SUPPORTED ENGLISH TEACHING

Aspect	Global Perspective	Chinese Perspective
Focus of AI usage in ELT	Primarily used for enhancing formative learning: providing feedback on writing, grammar practice, and other language skills improvement in classroom or tutoring contexts.	Employed for exam-oriented tasks and language drills: e.g., automated essay scoring, pronunciation correction, and speaking practice, aligning with curriculum goals.
Policy and support	No unified national policy exists in many Western countries; instead, integration is often guided by school- or district-level initiatives and international frameworks, such as the UNESCO AI in Education guidelines [8].	Since 2021, China has demonstrated strong top-down support for AI integration through national initiatives such as the Smart Education strategy, which encourages AI adoption in teaching. Local education bureaus have followed up by actively piloting AI programs [4].
Adoption and infrastructure	Gradual and varied adoption; well-resourced schools and universities often lead, but many institutions still in	Rapid but uneven adoption; urban and private schools implement AI tools more readily, while rural schools lag due

Aspect	Global Perspective	Chinese Perspective
	exploratory phase.	to limited internet and hardware infrastructure.
Examples of tools	Intelligent tutoring systems, writing assistants (e.g., grammar checkers, essay scoring like ETS's e-rater) are used for practice and assessment in some contexts.	Domestic AI tools (e.g., Deep Seek) integrated into lesson planning; Chinese-developed apps for English learning (writing and speaking) are being trialed in classrooms.

TABLE 2: COMPARISON OF KEY THEMES IN SUPPORTED ENGLISH TEACHING (GLOBAL VS. CHINESE CONTEXTS), HIGHLIGHTING WHAT DIFFERENT RESEARCHERS EMPHASIZE FOR EACH ASPECT OF INTEGRATION

Aspect	Global Perspectives	Chinese Perspectives
AI-supported lesson design	AI is used to co-create engaging learning materials and activities. Studies report improved student outcomes (e.g., better writing complexity) when AI tools like chat-bots or intelligent tutors assist in lesson tasks [9], [3]. Researchers emphasize the creative potential of AI to generate diverse language exercises and provide multimedia content, while also noting the need for teachers to vet AI-generated materials for quality and curricular fit [1], [2].	Teachers are incorporating AI tools such as Deep Seek to design English lesson content, including writing prompts and dialogues, making lessons more interactive. [10], [11]. Preliminary evidence from pilot programs suggests that AI-designed tasks can enhance student engagement and support differentiated instruction [12], [13]. However, Chinese educators emphasize the importance of aligning AI-generated materials with national curriculum standards and maintaining teacher oversight to ensure educational relevance [13].
AI-driven formative assessment	AI tools, such as automated essay scoring systems and speech analyzers, provide instant feedback and frequent practice opportunities, enhancing learning by quickly addressing errors [15]. Studies suggest that such tools improve grammar and pronunciation and ease teachers' workload. However, international organizations and scholars emphasize that human teachers are still essential for evaluating the depth and creativity of student output [16].	English teachers are increasingly experimenting with AI tools—such as automated writing evaluation systems and speech recognition software—for low-stakes assessments in writing and speaking. Classroom-based studies have shown that AI-generated feedback can raise learners' awareness of language use and foster iterative self-correction [17]. Chinese studies also emphasize the value of a hybrid approach: AI systems are well-suited to handle routine assessments such as identifying grammar or pronunciation errors, while human

Aspect	Global Perspectives	Chinese Perspectives
		teachers continue to provide feedback on idea development and text organization, ensuring comprehensive evaluation [12], [13].
Teacher professional development	Successful AI integration in education is strongly associated with teacher training and technological confidence. International studies show that while many educators express positive attitudes toward AI, they often lack formal training or established frameworks for implementation [18], [6]. Scholars emphasize the need for robust professional development and the dissemination of best practices to help teachers effectively integrate AI tools into pedagogy and address issues such as techno phobia and digital skill gaps [2], [4].	Chinese teachers generally view AI as a valuable tool for teaching and are inclined to adopt it. However, many report a lack of clear guidance on how to integrate AI into lesson planning, and there are currently few official pedagogical models to follow. Recent studies indicate a strong need for targeted training programs, updated teacher education curricula, and the development of communities of practice focused on AI-enhanced instruction to build teachers' capacity and technological confidence [19].
Ethical and policy considerations	Scholars worldwide urge careful consideration of data privacy, algorithmic bias, and transparency in AI tools [21], [22]. There is a consensus that clear ethical guidelines and policies must accompany AI deployment in schools, including protecting student data and ensuring AI recommendations do not reinforce biases or inequities [23], [24]. Several countries and international bodies have begun drafting principles for ethical AI in education, though implementation is in early stages.	Chinese research and policy documents echo global ethical concerns, emphasizing data security and culturally appropriate AI use in classrooms [24] . At the same time, China's government has been proactive in issuing directives—such as the Smart Education initiatives—to integrate AI in education [25]. These policies promote innovation while calling for oversight and continuous evaluation of AI's impact on teaching and learning. Recent policy frameworks also acknowledge structural challenges, such as unequal access to technology and infrastructure. In response, national initiatives include increased investment in rural school technology and the development of unified national teacher training standards for AI education [26].

B. Teacher Preparedness for AI and Pedagogical Shift

It is widely accepted that teacher readiness is a critical factor in the successful implementation of AI-enhanced

instruction. Recent studies show that many Chinese K – 12 teachers hold positive attitudes toward AI but lack structured pedagogical models or formal training guidelines for effective integration [19], [6], [18]. Additionally, the digital competence divide between urban and rural educators remains significant. Middle school teachers, in particular, face practical challenges in aligning AI-supported activities with national curricular standards [20]. These professional development challenges are summarized in Table 3.

TABLE 3: COMPARISON OF TEACHER PROFESSIONAL DEVELOPMENT CHALLENGES IN AI INTEGRATED ENGLISH TEACHING

Challenge	Global Context	Chinese Context
Lack of training and guidelines	Limited formal training programs on educational AI; teachers often must learn on their own or through ad-hoc workshops.	Few official training opportunities on AI pedagogy; educators lack clear models or policies to follow for AI integration.
Integrating AI into pedagogy	Uncertainty on how to incorporate AI into existing curricula and teaching methods; need for examples and frameworks.	No established pedagogical frameworks from authorities; teachers are unsure how to align AI tools with mandated curriculum requirements.
Digital competency gaps	Varied technical skills among teachers globally; some struggle with new technologies, especially older or under-resourced educators.	Significant urban-rural divide in tech skills; teachers in less developed regions lack confidence and infrastructure to use AI effectively.
Attitudes and concerns	Mixed sentiments: some teachers fear AI could replace aspects of their role or feel skeptical of its benefits, while others embrace it cautiously.	Generally positive attitude toward AI's potential, but concerns remain about over-reliance on automation and loss of teacher agency in AI-driven classrooms.
Support and workload	Need for administrative and technical support; without support, adding AI tools can increase teacher workload and stress.	Heavy teaching loads and exam pressures leave little time to experiment with AI; lack of support and recognition makes it hard for teachers to innovate with AI.

One subject area that has stepped boldly into the breach is English, where teachers who are starting to become early adopters of AI in the lesson design process. Given that language instruction is already laden with frequent assessment and feedback cycles, AI fits more naturally into their pedagogy. In several Chinese pilot programs, educators are beginning to explore the use of AI platforms such as Deep Seek to co-design writing tasks, generate oral practice materials, and deliver instant formative feedback. Though largely

concentrated in higher education at present, this trend is gradually expanding into secondary education settings [27], [28]. Yet fears remain about over-dependence on automation, the disenfranchisement of teacher agency, and the ethical ramifications of AI-infused contexts.

C. Lesson Design with AI

One of the areas of the deepest transformative potential of AI is in the design of lessons and tasks. Rather than merely providing static content, AI may co-create materials such as writing prompts, scaffold-ed grammar explanations, or simulated communicative scenarios using tools like Deep Seek or Chat GPT. For instance, recent studies have shown that writing exercises assisted by Chat GPT can support students in producing more complex and accurate written language, including more precise usage of verbs [29].

Aided by AI, modular lesson structures have emerged in Chinese middle school classrooms, where AI-generated input materials are combined with interactive grammar, vocabulary, and fluency activities. Building on principles of collaborative dialogue, recent frameworks have proposed a “blended task cycle” that begins with peer discussion centered on AI-generated stimuli, followed by teacher-led discussion and extension. This design keeps the pedagogy human-centered while enhancing it with AI support. The challenge is to integrate the official curriculum while maintaining creativity, spontaneity, and teacher agency. Table 4 presents an overview of emerging AI-assisted lesson design models [30], [31].

TABLE 4: SUMMARY OF AI-ASSISTED LESSON DESIGN AND TASK CONSTRUCTION MODELS

Model/Approach	Description & Examples
AI-assisted content creation	Teachers and AI co-create lesson content. For example, an AI tool generates dialogues or reading passages which the teacher then adapts for the class. This saves time and provides a variety of language inputs.
Chat GPT - aided writing tasks	Using large language models like Chat GPT to generate writing prompts or provide students with feedback on drafts is becoming increasingly common in educational settings. Studies show that, when used with proper guidance, these tools can enhance the complexity and accuracy of student writing [29], [32].
Modular AI-driven lessons	Lessons structured in modules, where each module includes AI-generated materials (texts, questions) followed by interactive tasks. This approach is being piloted in some Chinese schools to personalize content and keep students engaged.
Blended AI-human task cycle	A mixed approach has been proposed in recent studies, where students first engage with AI-generated stimuli or exercises, then participate in peer discussion, and finally the teacher intervenes to discuss and extend the learning. This ensures that AI use is

Model/Approach	Description & Examples
	balanced with human instruction. For instance, [33] describe a classroom interaction model where large AI models support initial content exploration, followed by teacher scaffolding. Similarly, [34] highlights the effectiveness of combining AI-based digital learning games with human feedback to enhance student understanding and engagement.

D. Student Engagement and Personalized Learning

Language learning and the personalization of learning paths are also being impacted by AI technologies.

Adaptive learning environments leverage intelligent tutoring systems that can assess student performance in real time, identify a student’s strengths and weaknesses, and customize content accordingly [35], [36]. In English language classrooms, such systems often take the form of pronunciation trainers, grammar corrector, and vocabulary games.

Students in Chinese middle schools respond positively to feedback provided through AI, especially when it is delivered in an interactive or gamified manner. Recent studies have shown that digital game-based AI tools can improve learners motivation, engagement, and academic performance in EFL and information technology classrooms [37], [38]. The personalized task assignment, from an AI generation of activity for the student, allows them to work at their own pace and seek guidance independently when needed. However, some researchers worry that personalization without purposeful scaffold can lead to fragmented learning experiences or superficial engagement. Thus, the teacher’s role remains critical in directing, guiding and contextualizing AI-mediated instruction.

E. AI-Enhanced Assessment and Feedback

As AI is introduced into language education, we are witnessing new ways of implementing formative and summative assessment, which is an essential part of language learning. Tools such as automated essay scoring (AES), speech recognition, and diagnostic feedback enable teachers to rapidly assess students’ grammar, coherence, fluency, and pronunciation. A recent systematic review of AI in English language teaching confirms that these tools can improve both the accuracy and efficiency of language assessment when combined with instructional feedback [39]. These systems also facilitate feedback to students much more frequently and more immediate than in traditional grading systems.

There is some evidence that in Chinese middle schools Deep Seek and similar assistive technologies have been used in low-stakes formative assessments,

especially for writing and oral presentations. According to teachers, AI-generated feedback makes students more conscious of how they are using language, and how this impacts their revision behavior. Researchers caution, however, that AES systems might prioritize superficial correctness over deeper rhetorical or creative qualities. That is why a hybrid model that combines AI-driven remark with teacher commenting was recommended to achieve efficiency and depth in evaluation.

F. Ethical, Infrastructural, and Policy-making Underpinnings

The expanding use of AI in English pedagogy also raises important ethical, infrastructural, and governance concerns. One recurring concern is data privacy — many AI implementations rely on collecting extensive student data, such as performance metrics, which complicates issues of consent, storage, and access [16]. For example, only 16% of countries explicitly guarantee data privacy in education by law, highlighting the global disparity in data protection measures [16]. Additionally, algorithmic bias can exacerbate inequalities when training data fail to adequately represent regional linguistic or cultural contexts. Studies show that biases in educational algorithms can significantly affect students from marginalized communities, reinforcing existing disparities [4].

From an infrastructure standpoint, the divide between urban and rural schools remains. Private and urban schools often have access to faster internet and newer devices, which facilitates the effective deployment of AI systems. In contrast, many public or rural schools lack the necessary hardware and technical support for AI integration. This gap in resources significantly limits the ability of rural schools to benefit from AI technologies [40]. Unless tackled through national and local policy efforts, these digital divides could accelerate achievement gaps.

In response, a few initiatives are getting off the ground. National-level guidelines have been issued by the Chinese Ministry of Education promoting “smart education,” and local governments are spending money to upgrade infrastructure and train teachers. However, there is a need for policy frameworks to develop further so that AI use is pedagogically sound, ethically responsible, and equitably distributed across diverse school settings.

IV. CONCLUSIONS

Integrating artificial intelligence (AI) in Chinese middle school English lesson design has allowed teachers to create interactive instructional materials and encourage students to think critically. But this requires, on one side, the readiness of teachers, and on the other side, addressing the related ethical issues and the challenges of inadequate infrastructure. Going forward, the emphasis needs to be on well-rounded teacher education, the creation of ethical guidelines and equitable distribution of resource allocation to facilitate responsible AI integration into education.

ACKNOWLEDGMENTS

I would like to express my deep gratitude to my supervisor, Dzintra Ilisko for her encouragement, guidance and constant care to me. She is an angle mentor whoever would dream to have.

My sincere thanks also go to my family-especially my husband and my mother and my mother in law, for their unconditional belief in me and great support. This journey would not have been possible without their sacrifices and emotional support.

Lastly, to my beloved daughter,心心, thank you for coming into my world. Your arrival gifted me the strength to grow beyond myself. I strive to be a role model you can look up to with pride. May my journey one day inspire yours.

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