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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

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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***	
	$\bar{x} \pm S\bar{x}$	$\bar{x} \pm S\bar{x}$	$\bar{x} \pm S\bar{x}$	$\bar{x} \pm S\bar{x}$	
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 (Ks), 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 Ks value ≥ 1.0 arbitrary units indicates high attention stability, characterized by consistent or improved performance throughout testing; Ks=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; Ks<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 ≥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±0.62% to 90.2±0.86% ($t=4.82$; $p<0.001$). 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±0.27%, increasing to 8.2±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±0.25% before the experiment to 7.4±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±0.62% ($t=4.82$; $p<0.001$), transitioning from medium to high

level; and an increase in attention shifting by 0.7±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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