Environment. Technology. Resources. Rezekne, Latvia
Proceedings of the 16th International Scientific and Practical Conference.2025. Volume III, 247-252

Enhancing Mining Education: Integrating Online Learning and Hands-on Experience for Comprehensive Skill Development

Karin Robam
Division of Mining and Mineral Technology
Tallinn University of Technology
Estonia
karin.robam@taltech.ee

Tony Hand
Division of Mining and Mineral Technology
Tallinn University of Technology
Estonia
tony.hand@taltech.ee

Sander Kanter
Division of Mining and Mineral Technology
Tallinn University of Technology
Estonia
sander.kanter@taltech.ee

Erik Väli
Division of Mining and Mineral Technology
Tallinn University of Technology
Estonia
erik.vali@taltech.ee

***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

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).

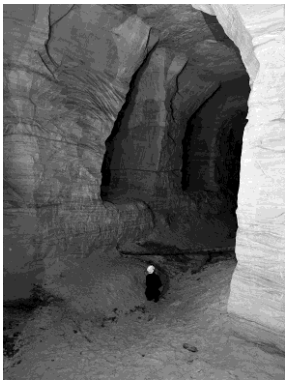

Fig. 1. Student Practical Experience and Measurements for Creating a 3D Model: Piusa Sand Caves, Estonia (Photo by S.Kanter).

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.).

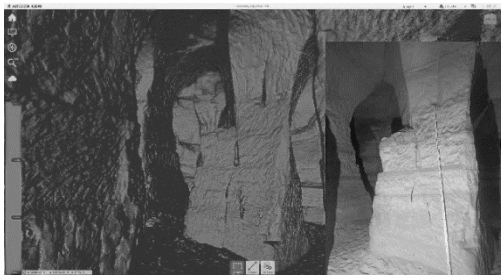

Fig.2. 3D Model Created After On-Site Measurement: Piusa Sand Caves, Estonia (by S. Kanter).

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.

References

[1] G. Ragannoud, 'Implementing the EU's Critical Raw Materials Act', Implementing the EU's Critical Raw Materials Act. [Online]. Available: https://www.europarl.europa.eu/RegData/etudes/BRIE/2024/766253/EPRS_BRI%282024%29766253_EN.pdf [Accessed: February 27, 2025].

[2] P. Hartlieb, L. Jorda Bordehore, M. Regueiro Y González-Barros, V. Correia, and J. Vidovic, 'A comprehensive skills catalogue for the raw materials sector and the structure of raw materials

education worldwide', *Min. Technol.*, vol. 129, no. 2, pp. 82–94, Apr. 2020. [Online]. Available: EBSCOhost, A comprehensive skills catalogue for the raw materials sector and the structure of raw materials education worldwide. - EBSCO [Accessed February 26, 2025], http://dx.doi.org/10.1080/25726668.2020.1770406.

[3] G. Spöttl and L. Windelband, 'The 4th industrial revolution – its impact on vocational skills', *J. Educ. Work*, vol. 34, no. 1, pp. 29–52, Jan. 2021. [Online]. Available: Taylor&Francis online, https://www.tandfonline.com [Accessed March 1, 2025]. https://doi.org/10.1080/13639080.2020.1858230

[4] D. Rotatori, E. J. Lee, and S. Sleeva, 'The evolution of the workforce during the fourth industrial revolution', *Hum. Resour. Dev. Int.*, vol. 24, no. 1, pp. 92–103, Jan. 2021. [Online]. Available: Semantic Scholar, https://www.semanticscholar.org [Accessed February 27, 2025]. https://doi.org/10.1080/13678868.2020.1767453

[5] A. Sahoo and D. Tripathy, 'Applications of AI and machine learning in mining: digitization and future directions', *Saf. Extreme Environ.*, vol. 7, Jan. 2025. [Online] Available: Springer Nature, https://link.springer.com [Accessed March 2, 2025]. https://doi.org/10.1007/s42797-025-00118-1

[6] A. Muresan, 'The European Green Deal's secret weapon: Education - European Commission'. Accessed: Feb. 21, 2025. [Online]. Available: European Commission, https://sustainable-energy-week.ec.europa.eu/news/european-green-deals-secret-weapon-education-2024-12-19_en

[7] A. Sörensen, R. Mitra, E. Hulthén, T. Hartmann, and E. Clausen, 'Bringing the Entrepreneurial Mindset into Mining Engineering Education', *Min. Metall. Explor.*, vol. 39, no. 4, pp. 1333–1344, Aug. 2022. [Online] Available: Springer Nature, https://link.springer.com [Accessed February 25, 2025]. https://doi.org/10.1007/s42461-022-00620-1

[8] F. Caputo, V. Cillo, F. Fiano, M. Pironti, and M. Romano, 'Building T-shaped professionals for mastering digital transformation', *J. Bus. Res.*, vol. 154, pp. 113309-, 2023. [Online] Available: ScienceDirect, https://www.sciencedirect.com [Accessed March 1, 2025] https://doi.org/10.1016/j.jbusres.2022.113309

[9] A. L. Steele, *Experiential Learning in Engineering Education*. Boca Raton: CRC Press, 2023.

[10] P. Dipitso, 'Work-Integrated Learning for Mining Engineering Training and the Employability Nexus in Traditional Research Universities: A Case of Selected South Africa Universities', *JCIHE*, vol. 12, no. 6S1, Feb. 2021. [Online] Available: OJED, https://ojed.org [Accessed February 25, 2025]. https://doi.org/10.32674/jcihe.v12i6S1.2192