Methodical foundations and implementation strategies for virtual reality in professional training of vocational higher education students

Yuliia V. Yechkalo[1], Viktoriia V. Tkachuk[1]

[1]*Kryvyi Rih National University, 11 Vitalii Matusevych Str., Kryvyi Rih, 50027, Ukraine*

Abstract

This paper presents a comprehensive exploration of the methodical foundations and implementation strategies for integrating virtual reality (VR) technologies in the professional training of students in vocational higher education. A detailed model for VR integration is presented, accompanied by an in-depth discussion of pedagogical conditions and evidence-based recommendations for effective use. The paper extensively examines the potential of virtual workshops and laboratories to enhance practical skills development, with a focus on industry-specific applications. Furthermore, it delves into the challenges and considerations for VR adoption, including technological, pedagogical, and institutional factors. The findings demonstrate that thoughtful VR integration, when part of a holistic educational approach, can significantly improve student engagement, motivation, and acquisition of professional competencies. The paper also discusses the implications of VR integration for curriculum design, assessment methods, and the changing role of educators in technology-enhanced learning environments.

1. Introduction

The rapid advancement of digital technologies is transforming educational practices across all sectors, with immersive technologies at the forefront of this revolution [1]. In vocational higher education, there is growing interest in using virtual reality (VR) to enhance the professional training of students [2]. VR offers unique affordances for creating realistic simulations of workplace environments, allowing students to practice skills in safe, controlled settings, and providing experiences that would be difficult or impossible to replicate in traditional educational contexts [3].

The potential benefits of VR in education are manifold. It can provide immersive, experiential learning opportunities that bridge the gap between theory and practice [4, 5]. VR simulations can expose students to a wide range of scenarios and equipment, some of which may be too costly, dangerous, or rare to encounter in physical training environments. Moreover, VR can enable repeated practice and instant feedback, potentially accelerating the learning process and improving skill retention [6].

However, the effective integration of VR into vocational curricula is not without challenges. It requires careful consideration of pedagogical approaches, technological infrastructure, institutional readiness, and the specific needs of different vocational fields [6]. There are also concerns about the potential drawbacks of VR, such as the risk of cognitive overload, the need for significant initial investment, and the importance of maintaining a balance with hands-on, real-world training.

This paper aims to provide comprehensive methodical foundations for implementing VR in the professional training of vocational higher education students. We present a detailed model for VR integration, outline key pedagogical conditions, and offer evidence-based recommendations for educators and institutions.

The research is motivated by several factors:

- The need to bridge the persistent gap between theoretical knowledge and practical skills in vocational education

AREdu 2023: 6th International Workshop on Augmented Reality in Education, May 17, 2023, Kryvyi Rih, Ukraine
uliaechk@gmail.com (Y. V. Yechkalo); viktoriya.tkachuk@gmail.com (V. V. Tkachuk)
0000-0002-0164-8365 (Y. V. Yechkalo); 0000-0002-5879-5147 (V. V. Tkachuk)

- The potential of VR to provide safe, cost-effective training for high-risk or resource-intensive professions
- The growing demand from industries for graduates with advanced technological skills
- The opportunity to increase student engagement and motivation through immersive learning experiences
- The need for vocational institutions to stay at the forefront of educational innovation

2. Background

2.1. Virtual reality in education

Virtual reality refers to computer-generated simulations of three-dimensional environments that can be interacted with in seemingly real or physical ways [7]. In educational contexts, VR allows for immersive, experiential learning through a variety of mechanisms:

- Creation of realistic workplace simulations that replicate the look, feel, and functionality of actual professional environments
- Visualization of complex processes and systems that may be difficult to observe or understand in the real world
- Hands-on practice of skills in safe, controlled environments where mistakes have no real-world consequences
- Gamified learning experiences that increase engagement and motivation
- Virtual field trips to locations or facilities that would be impractical to visit physically
- Collaborative virtual spaces where students can work together on projects regardless of physical location

The immersive nature of VR can lead to a sense of presence, where users feel as if they are actually in the simulated environment. This can enhance the emotional and cognitive engagement of learners, potentially leading to deeper understanding and better retention of information [6, 8].

Studies have shown that VR can increase student engagement, motivation, and knowledge retention compared to traditional instructional methods [6]. For example, research in medical education has demonstrated that VR simulations can improve surgical skills and reduce training time [9]. In engineering education, VR has been used to enhance spatial understanding and design skills [10].

However, challenges remain around several key issues:

- The cost of high-quality VR systems may limit widespread adoption, as they can be expensive
- Developing and maintaining VR systems requires specialized technical expertise
- Complex VR environments may increase cognitive load, potentially overwhelming some learners, particularly novices
- Extended use of VR can cause physical discomfort or motion sickness for some users
- Ensuring equitable access to VR technology for all students can be difficult

These challenges underscore the need for careful planning and implementation when integrating VR into educational programs.

2.2. Professional training in vocational higher education

Vocational higher education aims to prepare students for specific occupations through a combination of theoretical knowledge and practical skills development. Key aspects of vocational education include:

- Hands-on training in job-specific competencies that directly relate to workplace tasks
- Industry partnerships that provide real-world exposure and work-based learning opportunities

- Focus on employability and career readiness, including soft skills development
- Alignment of curriculum with industry standards and emerging technologies
- Emphasis on problem-solving and critical thinking in job-relevant contexts
- Integration of theory and practice through applied learning approaches

Traditional methods of vocational training often involve a combination of classroom instruction, laboratory work, workshops, and internships. While these approaches have proven effective, they can be limited by factors such as equipment costs, safety concerns, and the ability to replicate diverse workplace scenarios [11].

VR offers promising applications in vocational training by allowing for realistic simulations of workplace scenarios and equipment that may be difficult, dangerous, or expensive to access in physical settings [12, 13]. For example:

- In healthcare education, VR can simulate complex medical procedures without risk to patients
- In engineering, VR can allow students to interact with virtual prototypes and test designs
- In hospitality training, VR can recreate diverse customer service scenarios
- In construction education, VR can provide safe exposure to hazardous work environments

However, it is crucial to recognize that VR should complement rather than replace traditional hands-on learning. The tactile experience of working with real tools and materials remains an essential component of vocational training. Therefore, the integration of VR must be done thoughtfully, as part of a blended learning approach that combines the best of both virtual and physical training methods.

3. Model for VR integration

Based on a comprehensive analysis of pedagogical literature and current best practices, we propose a detailed model for integrating VR into professional training programs in vocational higher education (figure 1). This model consists of five interconnected components, each playing a crucial role in ensuring effective and purposeful use of VR technology.

3.1. Goal block

The foundation of effective VR integration lies in clear, well-defined learning objectives that align VR activities with overall curriculum goals and industry skill requirements. This component involves:

- Conducting a thorough needs analysis to identify areas where VR can add significant value
- Collaborating with industry partners to ensure relevance to current workplace demands
- Defining specific, measurable, achievable, relevant, and time-bound (SMART) objectives for VR-enhanced learning
- Identifying the particular skills or competencies that VR is best suited to develop
- Considering both technical skills and soft skills (e.g., communication, problem-solving) in objective setting

Examples of well-defined goals might include:

- Developing proficiency in operating specific machinery or equipment
- Improving decision-making skills in high-pressure scenarios
- Enhancing spatial awareness and design capabilities
- Increasing confidence in performing complex procedures

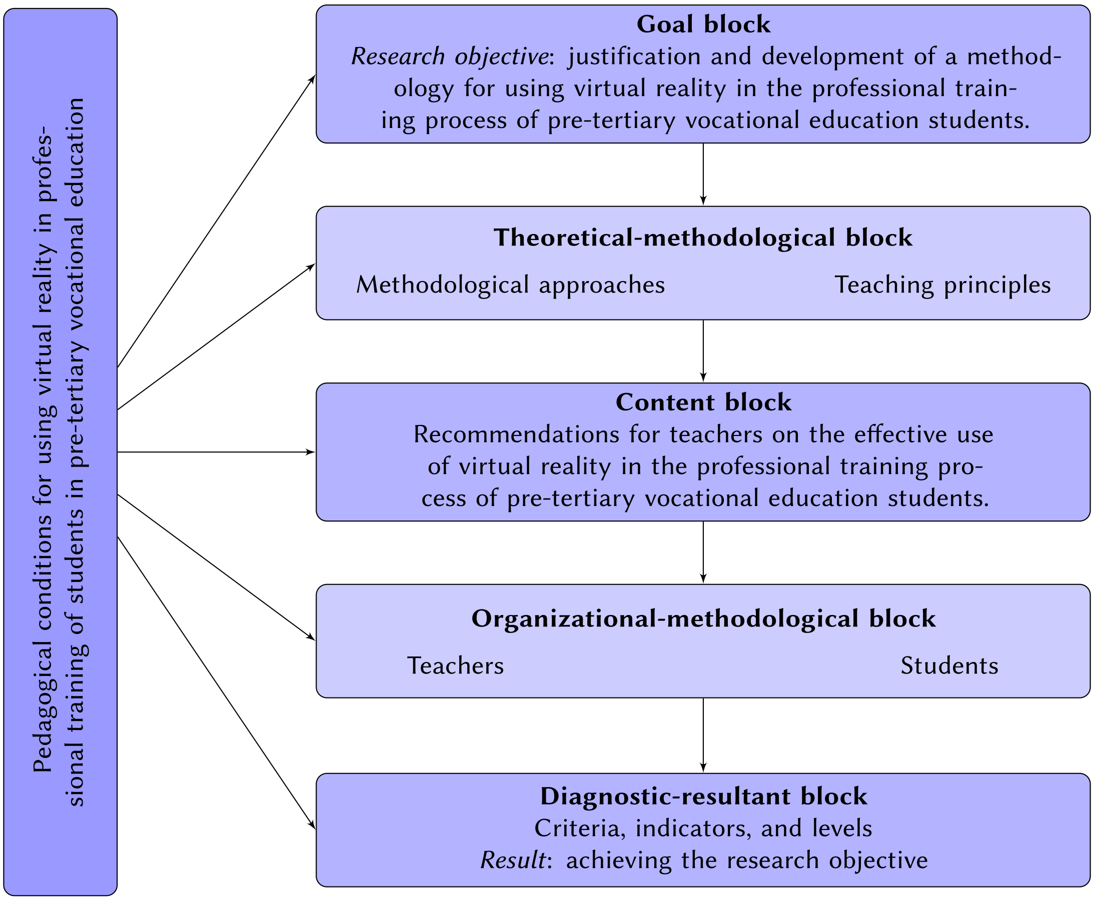

Figure 1: Comprehensive model for integrating VR in vocational higher education.

3.2. Theoretical-methodological block

The pedagogical framework should draw on established learning theories while using the unique affordances of VR. Key principles and strategies include:

- *Experiential learning*, incorporating Kolb's experiential learning cycle in VR simulations, where students engage in experiencing, reflecting, conceptualizing, and actively experimenting
- *Situated learning* by designing authentic contexts that mirror real-world applications of knowledge
- *Scaffolded skill development* through a sequence of VR activities that become progressively more complex and challenging
- *Collaborative learning*, offering opportunities for peer interaction and teamwork in virtual environments
- *Constructivist approaches* that prompt students to actively build knowledge through exploration and problem-solving
- *Multimodal learning*, using VR's visual, auditory, and kinesthetic features to address various learning styles
- *Adaptive learning*, employing data analytics from VR systems to customize learning experiences based on individual student performance [14]

3.3. Content block

VR learning content and activities should be carefully designed to achieve defined learning objectives while taking full advantage of the technology's capabilities:

- *Realistic modeling*, creating high-fidelity representations of workplace environments, equipment, and processes
- *Interactive elements*, designing intuitive interactions that allow for active learning and experimentation
- *Scenario-based learning*, developing a range of scenarios that reflect real-world challenges and decision points
- *Gamification*, incorporating game-like elements such as points, levels, and challenges to increase engagement
- *Feedback mechanisms*, implementing immediate, constructive feedback to guide student learning
- *Difficulty scaling*, creating content with adjustable levels of complexity to accommodate different skill levels
- *Cultural sensitivity*, ensuring content is inclusive and respectful of diverse backgrounds
- *Accessibility features*, incorporating options to accommodate students with different abilities

3.4. Organizational-methodological block

Effective implementation of VR in the curriculum requires careful planning and execution:

- *Technology infrastructure*, ensuring adequate hardware, software, and network capabilities to support VR systems
- *Instructor training*, providing comprehensive professional development for faculty on both technical and pedagogical aspects of VR
- *Student orientation*, developing structured introduction sessions to familiarize students with VR technology and safety protocols
- *Integration with curriculum*, seamlessly incorporating VR activities into existing course structures and learning pathways
- *Support systems*, establishing technical support mechanisms for troubleshooting and maintenance
- *Scheduling and access*, creating efficient systems for student access to VR resources, especially if equipment is limited
- *Health and safety*, implementing guidelines to ensure safe and comfortable use of VR equipment
- *Ethical considerations*, addressing privacy concerns and data management in VR learning environments

3.5. Diagnostic-resultant block

Ongoing assessment and evaluation are crucial to refine and improve VR implementation:

- *Learning outcomes*, measuring achievement of defined learning objectives through appropriate assessment methods
- *User experience*, gathering detailed student and instructor feedback on the usability and effectiveness of VR activities
- *Engagement metrics*, analyzing data on student participation, time spent, and progress in VR environments
- *Comparative analysis*, conducting studies to compare outcomes between VR-enhanced and traditional learning approaches
- *Skill transfer*, assessing the degree to which skills learned in VR translate to real-world performance
- *Cost-benefit analysis*, evaluating the return on investment in terms of educational outcomes and resource utilization
- *Longitudinal studies*, tracking long-term impacts on student career readiness and professional success
- *Continuous improvement*, using evaluation data to iteratively refine VR content, implementation strategies, and pedagogical approaches

4. Pedagogical conditions for effective VR use

Our analysis identified two key pedagogical conditions that should be established for effective use of VR in professional training. These conditions are crucial for creating an environment where VR can truly enhance the learning experience and contribute to the development of professional competencies.

4.1. Motivation for professional activities

Enhancing student motivation for their chosen profession is a critical factor in the success of vocational education. VR activities should be carefully designed to increase this motivation by:

- Providing realistic previews of workplace environments, offering immersive experiences that give students a tangible sense of their future work settings, helping to solidify their career choices and increase commitment to their studies
- Allowing experimentation with job tasks in low-stakes settings, enabling students to try out various professional tasks without real-world consequences, building confidence and reducing anxiety about future job performance
- Demonstrating relevance of theoretical concepts to practice, bridging the gap between abstract concepts and practical application, helping students understand the importance of their theoretical studies
- Gamifying skill development, incorporating game-like elements such as challenges, rewards, and progress tracking to make skill acquisition more engaging and enjoyable
- Facilitating goal-setting and progress monitoring, helping students set personal learning goals and track their progress, fostering a sense of achievement and growth
- Enabling exploration of career paths, allowing students to experience different specializations within their field, aiding them in making informed decisions about their career trajectories
- Fostering a sense of professional identity, using immersive experiences in professional settings to help students begin to see themselves as members of their chosen profession, increasing motivation to excel

4.2. Integration of VR methodology

To ensure that VR is not just a novelty but an integral and effective part of the learning process, a clear methodology for VR integration should be developed and implemented:

- Aligning VR activities with curriculum learning objectives, ensuring each VR experience has a clear purpose and is directly linked to specific learning outcomes defined in the curriculum
- Providing adequate technical and pedagogical support for instructors, offering comprehensive training and ongoing support to help educators effectively incorporate VR into their teaching practices
- Ensuring accessibility and ease-of-use for all students, designing VR systems with inclusivity in mind to accommodate different learning styles and physical abilities
- Combining VR with other teaching methods in a blended approach, using VR to complement, not replace, other effective teaching methods, creating a balanced and diverse learning experience
- Developing assessment strategies for VR-based learning, creating new methods of evaluation to accurately assess skills and knowledge gained through VR experiences
- Creating a feedback loop for continuous improvement, regularly collecting and analyzing data from VR sessions to inform ongoing refinement of the technology and its implementation
- Integrating VR across the curriculum, weaving VR throughout the educational program where appropriate, rather than treating it as an isolated tool
- Fostering a culture of innovation and technological literacy, encouraging both students and faculty to embrace new technologies and continuously explore their potential in education

- Developing guidelines for appropriate use, establishing clear protocols for when and how VR is used, ensuring it is employed where it adds the most value to the learning experience
- Collaborating with industry partners, engaging with employers to ensure VR simulations reflect current industry practices and technologies

5. Virtual workshops and laboratories

A particularly promising application of VR in vocational training is the creation of virtual workshops and laboratories [15, 16]. These immersive environments offer unique opportunities for skill development and experiential learning [17, 18]. In virtual workshops and labs, students can:

- Practice using specialized equipment and tools, gaining familiarity with a wide range of industry-specific tools and machinery, including those that might be too expensive or dangerous for frequent hands-on use
- Conduct experiments and simulations, exploring complex scientific processes or engineering principles in detail, with the ability to manipulate variables and observe outcomes in real-time
- Troubleshoot realistic workplace scenarios, encountering and solving common (and uncommon) problems they might face in their future careers, developing critical thinking and problem-solving skills
- Collaborate on team projects, using virtual environments to facilitate group work and allowing students to collaborate on complex tasks regardless of physical location
- Explore dangerous or hard-to-access environments, simulating hazardous conditions or remote locations to gain valuable experience without risk
- Visualize abstract concepts, rendering complex theories or microscopic processes in 3D to make them easier to understand and remember

Key features of effective virtual workshops include:

- High-fidelity 3D modeling of real-world environments, ensuring the virtual environment is realistic and transferable to real-world skills
- Physics-based interactions with objects and machinery, accurately simulating how objects behave and interact to enhance the learning experience
- Customizable scenarios of varying complexity, providing the ability to adjust difficulty levels for scaffolded learning experiences
- Data collection and analysis tools, allowing students to track their performance and learn from their actions
- Instructor monitoring and intervention capabilities, enabling teachers to observe student activities and provide guidance as needed
- Multi-user functionality, facilitating collaborative learning and team projects by allowing multiple users in the same virtual space
- Integration with learning management systems, seamlessly tracking student progress and assessments
- Haptic feedback, enhancing the realism of the experience by incorporating tactile sensations where possible

Virtual workshops can be particularly valuable in the following contexts:

- High-risk or high-cost training scenarios, such as in fields like aviation, nuclear energy, or advanced manufacturing
- Replicating rare or dangerous situations, such as emergency response training or handling hazardous materials

- Allowing repeated practice to build muscle memory, which is particularly useful for developing procedural skills or refining techniques
- Simulating equipment not physically available, exposing students to a wider range of tools and technologies than a physical workshop could provide
- Scale and perspective shifting, enabling students to explore environments at different scales, from the microscopic to the architectural
- Rapid prototyping and design iteration, speeding up the prototyping process in fields like engineering or product design

It is crucial to emphasize that virtual workshops should complement rather than replace hands-on training with real equipment. A blended approach that combines VR and physical practice is likely to be the most effective for skill development, allowing students to benefit from the advantages of both virtual and real-world learning environments.

6. Implementation recommendations

Based on our analysis and the experiences of early adopters, we offer the following detailed recommendations for institutions looking to implement VR in vocational training programs. We strongly advocate beginning with small-scale pilot projects, which allow institutions to test effectiveness and gather feedback in a single course or module before attempting wider implementation. This approach enables refinement of methodologies and systems before full-scale deployment.

Critical to success is the provision of comprehensive training for instructors, encompassing both technical training on VR systems and pedagogical guidance for effective integration into teaching practices. The establishment of a community of practice can provide valuable ongoing peer support. Additionally, careful alignment with existing curriculum is essential, with VR activities being precisely mapped to established learning objectives and competency frameworks. It is crucial to avoid implementing VR solely for its novelty; each application should serve a clear pedagogical purpose.

Institutions should develop clear guidelines for VR use, establishing specific protocols that delineate when VR is more appropriate than traditional methods. These protocols should take into account various factors including learning objectives, student readiness, and resource availability. The development of industry partnerships is also vital, enabling collaboration with employers to ensure VR simulations accurately reflect current workplace practices and technologies, while potentially offering opportunities for co-development of VR content.

Continuous evaluation and refinement should be fundamental to the implementation process. This requires the establishment of robust assessment mechanisms to measure VR's impact on learning outcomes, with the resulting data being used to iteratively improve integration. Accessibility must be carefully considered, ensuring VR systems are usable by students with different physical abilities and providing alternatives for students who cannot use VR due to health concerns such as motion sickness.

Health and safety considerations should be formalized through specific guidelines covering time limits, ergonomic setup, and hygiene practices for shared equipment. While off-the-shelf VR applications can be valuable, institutions should consider investing in quality content development, potentially creating custom content tailored to specific curriculum needs. Technology lifecycle planning is essential, requiring budgeting for regular updates and replacements of VR hardware and software, given the rapid evolution of technology in this field.

Adequate technical support is crucial, necessitating IT staff trained in VR system troubleshooting and readily available during class times. Integration with other educational technologies should be considered, examining how VR can complement existing tools such as learning management systems, digital textbooks, and online collaboration platforms. Institutions should foster a culture of innovation, encouraging faculty and students to experiment with VR and share experiences, potentially through showcases or competitions for VR projects.

Institutional change preparation is necessary, as VR integration may require adjustments to teaching spaces, schedules, and assessment methods. These changes should be planned proactively. Ethical considerations must be addressed through policies covering data privacy, content appropriateness, and potential psychological impacts of immersive experiences. Finally, scalability should be considered as institutions move beyond pilot projects, examining how VR can be implemented across multiple courses or programs in a cost-effective manner.

7. Challenges and considerations

While VR offers significant potential benefits for vocational training, several challenges and considerations must be carefully evaluated for successful implementation. The high initial costs of VR hardware and software represent a significant barrier, requiring institutions to carefully consider return on investment and explore various funding options. This financial consideration is compounded by the need for ongoing technical support, as VR systems require regular maintenance, updates, and troubleshooting, necessitating dedicated technical staff with specialized knowledge.

Student comfort and wellbeing present another crucial consideration, as some users may experience motion sickness or eye strain with prolonged VR use. Institutions must establish clear protocols to address these issues. Additionally, cognitive overload can occur if VR environments are too complex or poorly designed, potentially overwhelming students rather than enhancing learning. This underscores the importance of careful instructional design in VR implementation.

The assessment of skills transfer poses a significant challenge, as it can be difficult to accurately measure how well skills learned in VR translate to real-world settings. This necessitates the development of robust assessment methods. Furthermore, institutions must strike a careful balance between virtual and hands-on practice, as there is a risk of overreliance on VR at the expense of crucial hands-on experience with real equipment.

The rapid pace of technological change in VR development means systems may become outdated quickly, requiring regular upgrades. This technical challenge is often accompanied by human factors, as some faculty may be resistant to incorporating VR into their teaching, highlighting the importance of change management and professional development programs.

Equity and access present ongoing challenges, as institutions must ensure all students have equal access to VR technology, both in and out of the classroom. Content development represents another significant hurdle, as creating high-quality, educationally effective VR content can be both time-consuming and expensive. Integration challenges also exist, as VR systems need to work seamlessly with other educational technologies and processes already in place.

Ethical considerations require careful attention, particularly regarding data privacy, content appropriateness, and psychological impact. Additionally, regulatory compliance must be addressed, as training methods in some fields need to meet specific regulatory requirements, which VR systems must satisfy.

These challenges and considerations should be carefully weighed against potential benefits when considering VR implementation. A thorough needs assessment and strategic planning process can help institutions effectively navigate these challenges while maximizing the educational potential of VR technology.

8. Conclusion

This paper has presented comprehensive methodical foundations for integrating virtual reality into professional training programs in vocational higher education. The proposed model and pedagogical conditions provide a structured framework for systematic VR implementation that aligns with curriculum goals and pedagogical best practices.

Virtual workshops and laboratories offer particularly promising applications for enhancing practical skills development in vocational education. By providing safe, repeatable, and customizable learning experiences, VR can significantly enhance the depth and breadth of training provided to students.

However, it is crucial to emphasize that VR should be viewed as a complement to, rather than replacement for, traditional hands-on training methods. A blended approach that combines the strengths of both virtual and physical learning environments is likely to yield the best results in terms of skill development and knowledge retention.

References

[1] S. H. Lytvynova, S. O. Semerikov, A. M. Striuk, M. I. Striuk, L. S. Kolgatina, V. Y. Velychko, I. S. Mintii, O. O. Kalinichenko, S. M. Tukalo, AREdu 2021 - Immersive technology today, in: S. H. Lytvynova, S. O. Semerikov (Eds.), Proceedings of the 4th International Workshop on Augmented Reality in Education (AREdu 2021), Kryvyi Rih, Ukraine, May 11, 2021, volume 2898 of *CEUR Workshop Proceedings*, CEUR-WS.org, 2021, pp. 1–40. URL: https://ceur-ws.org/Vol-2898/paper00.pdf.

[2] R. R. Ravichandran, J. Mahapatra, Virtual Reality in Vocational Education and Training: Challenges and Possibilities, Journal of Digital Learning and Education 3 (2023) 25–31. doi:10.52562/jdle.v3i1.602.

[3] Amin, I. Widiaty, C. Yulia, A. G. Abdullah, The Application of Virtual Reality (VR) in Vocational Education, in: Proceedings of the 4th International Conference on Innovation in Engineering and Vocational Education (ICIEVE 2021), Atlantis Press, 2022, pp. 112–120. doi:10.2991/assehr.k.220305.024.

[4] S. O. Semerikov, T. A. Vakaliuk, I. S. Mintii, V. A. Hamaniuk, O. V. Bondarenko, P. P. Nechypurenko, S. V. Shokaliuk, N. V. Moiseienko, Development of digital competencies in immersive cloud-based educational environment, CEUR Workshop Proceedings 3781 (2024) 203–208. URL: https://ceur-ws.org/Vol-3781/paper27.pdf.

[5] S. O. Semerikov, T. A. Vakaliuk, I. S. Mintii, V. A. Hamaniuk, V. N. Soloviev, O. V. Bondarenko, P. P. Nechypurenko, S. V. Shokaliuk, N. V. Moiseienko, D. S. Shepiliev, Immersive E-Learning Resources: Design Methods, in: Digital Humanities Workshop, DHW 2021, Association for Computing Machinery, New York, NY, USA, 2022, p. 37–47. doi:10.1145/3526242.3526264.

[6] C. Udeozor, R. Toyoda, F. R. Abegão, J. Glassey, Perceptions of the use of virtual reality games for chemical engineering education and professional training, Higher Education Pedagogies 6 (2021) 175–194. doi:10.1080/23752696.2021.1951615.

[7] S. O. Semerikov, T. A. Vakaliuk, I. S. Mintii, V. A. Hamaniuk, O. V. Bondarenko, P. P. Nechypurenko, S. V. Shokaliuk, N. V. Moiseienko, Immersive cloud-based educational environment of the university: Design principles, CEUR Workshop Proceedings 3771 (2024) 126–135. URL: https://ceur-ws.org/Vol-3771/paper27.pdf.

[8] T. H. Kramarenko, O. S. Kochina, The use of immersive technologies in teaching mathematics to vocational students, Journal of Physics: Conference Series 2611 (2023) 012006. doi:10.1088/1742-6596/2611/1/012006.

[9] L. Mekacher, Augmented reality (AR) and virtual reality (VR): The future of interactive vocational education and training for people with handicap, PUPIL: International Journal of Teaching, Education and Learning 3 (2019) 118–129. doi:10.20319/pijtel.2019.31.118129.

[10] J. Spilski, C. Giehl, S. Schlittmeier, T. Lachmann, J.-P. Exner, A. Makhkamova, D. Werth, M. Pietschmann, Potential of VR in the Vocational Education and Training of Craftsmen, in: Proc. 19th International Conference on Construction Applications of Virtual Reality (CONVR), Bangkok, Thailand, 2019, 2019. URL: https://www.researchgate.net/publication/337339626.

[11] S. L. Kucher, R. M. Horbatiuk, M. M. Ozhha, N. M. Hryniaieva, Use of information and communication technologies in the organization of blended learning of future vocational education professionals, in: S. Papadakis (Ed.), Proceedings of the 11th Workshop on Cloud Technologies in Education (CTE 2023), Kryvyi Rih, Ukraine, December 22, 2023, volume 3679 of *CEUR Workshop Proceedings*, CEUR-WS.org, 2023, pp. 54–66. URL: https://ceur-ws.org/Vol-3679/paper39.pdf.

[12] J. Man, F. Guo, C. Ma, Innovative Analysis of Higher Vocational Education Model Based on Virtual Reality Technology, Journal of Physics: Conference Series 1533 (2020) 022097. doi:10.1088/1742-6596/1533/2/022097.

[13] O. O. Lavrentieva, I. O. Arkhypov, O. P. Krupski, D. O. Velykodnyi, S. V. Filatov, Methodology of

using mobile apps with augmented reality in students' vocational preparation process for transport industry, in: O. Y. Burov, A. E. Kiv (Eds.), Proceedings of the 3rd International Workshop on Augmented Reality in Education, Kryvyi Rih, Ukraine, May 13, 2020, volume 2731 of *CEUR Workshop Proceedings*, CEUR-WS.org, 2020, pp. 143–162. URL: https://ceur-ws.org/Vol-2731/paper07.pdf.

[14] L. Fadieieva, S. Semerikov, Exploring the Interplay of Moodle Tools and Student Learning Outcomes: A Composite-Based Structural Equation Modelling Approach, in: E. Faure, Y. Tryus, T. Vartiainen, O. Danchenko, M. Bondarenko, C. Bazilo, G. Zaspa (Eds.), Information Technology for Education, Science, and Technics, volume 222 of *Lecture Notes on Data Engineering and Communications Technologies*, Springer Nature Switzerland, Cham, 2024, pp. 418–435. doi:10.1007/978-3-031-71804-5_28.

[15] P. Nechypurenko, T. Selivanova, M. Chernova, Using the Cloud-Oriented Virtual Chemical Laboratory VLab in Teaching the Solution of Experimental Problems in Chemistry of 9th Grade Students, in: V. Ermolayev, F. Mallet, V. Yakovyna, V. S. Kharchenko, V. Kobets, A. Kornilowicz, H. Kravtsov, M. S. Nikitchenko, S. Semerikov, A. Spivakovsky (Eds.), Proceedings of the 15th International Conference on ICT in Education, Research and Industrial Applications. Integration, Harmonization and Knowledge Transfer. Volume II: Workshops, Kherson, Ukraine, June 12-15, 2019, volume 2393 of *CEUR Workshop Proceedings*, CEUR-WS.org, 2019, pp. 968–983. URL: https://ceur-ws.org/Vol-2393/paper_329.pdf.

[16] P. Nechypurenko, O. Evangelist, T. Selivanova, Y. O. Modlo, Virtual Chemical Laboratories as a Tools of Supporting the Learning Research Activity of Students in Chemistry While Studying the Topic "Solutions", in: O. Sokolov, G. Zholtkevych, V. Yakovyna, Y. Tarasich, V. Kharchenko, V. Kobets, O. Burov, S. Semerikov, H. Kravtsov (Eds.), Proceedings of the 16th International Conference on ICT in Education, Research and Industrial Applications. Integration, Harmonization and Knowledge Transfer. Volume II: Workshops, Kharkiv, Ukraine, October 06-10, 2020, volume 2732 of *CEUR Workshop Proceedings*, CEUR-WS.org, 2020, pp. 984–995. URL: https://ceur-ws.org/Vol-2732/20200984.pdf.

[17] S. O. Semerikov, M. M. Mintii, I. S. Mintii, Review of the course "Development of Virtual and Augmented Reality Software" for STEM teachers: implementation results and improvement potentials, in: S. H. Lytvynova, S. O. Semerikov (Eds.), Proceedings of the 4th International Workshop on Augmented Reality in Education (AREdu 2021), Kryvyi Rih, Ukraine, May 11, 2021, volume 2898 of *CEUR Workshop Proceedings*, CEUR-WS.org, 2021, pp. 159–177. URL: https://ceur-ws.org/Vol-2898/paper09.pdf.

[18] O. Tsvetkova, O. Piatykop, A. Dzherenova, O. Pronina, T. A. Vakaliuk, I. Fedosova, Development and implementation of virtual physics laboratory simulations for enhanced learning experience in higher education, in: S. Papadakis (Ed.), Proceedings of the 11th Workshop on Cloud Technologies in Education (CTE 2023), Kryvyi Rih, Ukraine, December 22, 2023, volume 3679 of *CEUR Workshop Proceedings*, CEUR-WS.org, 2023, pp. 98–110. URL: https://ceur-ws.org/Vol-3679/paper10.pdf.