Specialized Training for Engineers using VR as part of Education 5.0

Mateusz Salach
Rzeszow University of Technology
Rzeszow, Poland
m.salach@prz.edu.pl

Andrzej Paszkiewicz
Rzeszow University of Technology
Rzeszow, Poland
andrzejp@prz.edu.pl

Arkadiusz Stęchły
Rzeszow University of Technology
Rzeszow, Poland
a.stechly@prz.edu.pl

Marek Bolanowski
Rzeszow University of Technology
Rzeszow, Poland
marekb@prz.edu.pl

Dominik Strzałka
Rzeszow University of Technology
Rzeszow, Poland
strzalka@prz.edu.pl

Abstract

Preparing society to function in a rapidly changing technological world requires changes to traditional teaching methods. These changes must also be implemented in the education of engineers across various specializations. This study focuses on the potential use of Virtual Reality (VR) environments to enhance the competencies of engineers in fields such as CNC systems, computer networks, digital electronics, etc. The conducted research, along with the implementation of dedicated VR environments for specific specializations, allows for the acquisition of valuable experience and knowledge in the development of this form of education—both within formal educational pathways and in supplementary learning. This work demonstrates the possibilities of adapting the didactic process to the evolving needs of industry through the use of VR.

Keywords

Virtual Reality, Education 5.0, CNC, Computer networks, Industry 4.0

How to cite this paper:
Mateusz Salach, Andrzej Paszkiewicz, Arkadiusz Stęchły, Marek Bolanowski, and Dominik Strzałka. 2025. Specialized Training for Engineers using VR as part of Education 5.0. In *Proceedings of ACM IMX Workshops, June 3 - 6, 2025*. SBC, Porto Alegre/RS, Brazil, 5 pages.
https://doi.org/10.5753/imxw.2025.9846

1 Introduction

Nowadays, we are witnessing the rapid development of modern technologies related to computer science, electronics, telecommunications, as well as automation and robotics. This development has a significant impact on various areas of social, economic, and cultural life, including the improvement of quality of life and the increase in industrial production efficiency. A proper step in this direction is the realization of the Education 5.0 concept, as it responds to the dynamic changes of the modern world and the requirements of the future labor market.

The concept of Society 5.0 [5] has been present in academic discourse for many years, addressing the role of individuals and society as a whole in the digital era [15]. One of the pillars of Society 5.0 is modern education [17], which plays a key role in preparing individuals for the challenges of the contemporary world. The implementation of innovative teaching methods is essential for adapting educational systems to a rapidly changing technological reality. One of the significant directions of development is the use of virtual (VR), augmented (AR), and mixed reality (MR) technologies in the educational process. Despite the growing use of VR in education, there is still a lack of solutions focused on specialized technical training.

The aim of the research work is to develop and evaluate the use of VR technology as an effective training tool enabling safe and widely accessible education of specialists in the field of operating advanced and hard-to-reach machines.

2 Background

The concept of Education 5.0 is based on interdisciplinarity and a holistic approach to knowledge. Modern education systems employ a wide range of teaching methods—from traditional tools such as blackboards and handwritten notes to advanced solutions, including interactive whiteboards, language models, and Extended Reality (XR) technologies [4]. These latter technologies enable interaction with digital environments without losing touch with the real world, representing a significant step toward a more engaging and effective learning process.

One of the most important pillars of Education 5.0 is the use of XR technologies which goes far beyond its original applications in computer gaming. Examples of its implementation can be observed in countries such as Thailand and Mexico [13, 16], where virtual reality contributes to improved learning outcomes by increasing immersion and interactivity. VR technology is used not only in engineering education, but also in medicine. It supports patient rehabilitation through dedicated VR applications [1], and plays a key role in teaching medical procedures by enabling simulations of surgeries and therapies [11]. Moreover, it is used in crisis response training, where interactive exercises allow emergency services to enhance their skills in highly realistic conditions [2]. Modern XR solutions are also being applied in numerous fields, including architecture [10], history [20], programming [7], dietetics [19], physics education [18] and even augmented reality-based tourism [9].

Part of Edu 5.0 teaching method is x-based learning such as game-based learning (GBL), which involves learning through computer games. Research conducted by scientists at Stockholm University shows that implementing gamification elements in teaching increases student engagement and improves the effectiveness of learning [6]. Findings presented in [12] demonstrate that combining VR with challenge-based learning (CBL) methodology leads to improved educational outcomes. The evolution of teaching methods is continuously adapting to emerging technologies and global educational trends.

3 VR in Education

This article focuses on the use of game-based learning methodology in combination with virtual reality. The potential of VR technology which includes both advanced headsets and software for designing dedicated educational environments is immense. However, for the developed solutions to fulfill their educational functions and be effective for young learners, the use of appropriate methodology is essential. Creating VR applications without prior problem analysis, clearly defined learning objectives, and practice-based learning does not lead to effective education.

Various models for designing VR applications have been developed to date [3, 8, 14], all of which are based on continuous project analysis and evaluation, allowing for systematic improvement and optimization of both solutions and processes. Creating VR applications without prior problem analysis, clearly defined learning objectives, and practice-based learning does not lead to effective education. Based on these models, VR applications have been created to familiarize students with the operation of specialized equipment and to help them acquire practical skills.

As part of the conducted work, three applications were developed to simulate different environments and problems that students from specific specializations must face. The developed solutions include a simulation for learning digital electronics, the operation of devices within a course on computer networks, and a training module for operating a computer numerical control (CNC) machine.

3.1 CNC Virtual Training Application

One of the developed solutions is a training simulator for operating the HAAS VF-1 CNC machine. The operation scenario is illustrated in Figure 1a. The main task of the user is to execute a program saved on a USB drive and run it on the CNC machine. The application guides the user through each stage, from turning on the machine and configuring it, to completing the machining process. During the training, the user may make mistakes, which trigger appropriate messages on the machine's interface. To support the learning process, key interface elements are highlighted with a yellow frame, indicating the next required step. The view of the HAAS machine digital twin is presented in Figure 1b with appropriate control panel next to the machine. The goal of the VR application is to replicate real working conditions as accurately as possible and to provide effective training in machine operation, allowing students to acquire the practical skills necessary in the industry.

Based on the analysis, the following project objectives were defined:

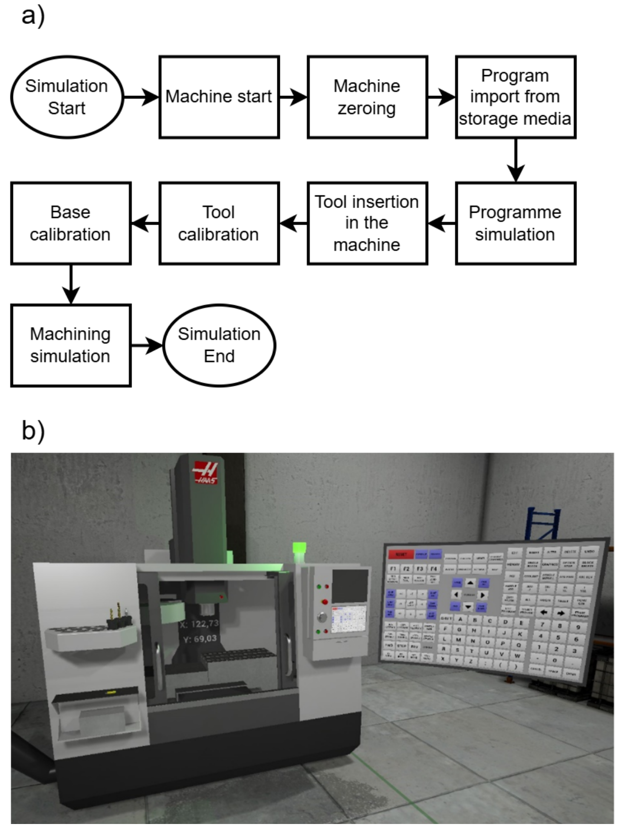

Figure 1: a) Scenario of the CNC VR-based educational application b) View of the HAAS VF-1 machine model with the control panel in the CNC VR application

- **Complete replication of the technological process** – the user must learn how to operate the machine step by step, from startup to the completion of the machining process, which requires an accurate simulation of all procedures.
- **Support for users with no prior experience in machine operation** – the application should guide the user through a system of visual cues, hints, and interactions, enabling them to complete the training independently.
- **Error detection and analysis system** – the user should be informed about mistakes they make, allowing them to improve their skills accordingly. A tracking module was implemented to analyze the correctness of operations and display relevant messages on the machine interface. Certain errors were intentionally triggered to draw attention to potential issues that may occur when working with the actual equipment.

To ensure the most accurate replication of real conditions, an on-site inspection and scenario testing were conducted on an actual HAAS VF-1 machine. After the course students emphasized that training was very educational for them, they were able to learn how to operate the real machine as the CNC was very accurately implemented.

3.2 Virtual Networking Environment for Engineers

Due to the key role that computer networks play in the modern world, the education of network engineers has a direct impact on virtually every area of contemporary life. It is important to recognize that computer networks form the foundation of operations for most businesses, institutions, public administration, and everyday life. Today's network infrastructure enables access to digital resources, the Internet of Things (IoT), cloud services, e-commerce, telemedicine, as well as remote work and learning. As a result, network engineers are responsible for designing the network infrastructure, as well as implementing and ensuring its proper functioning. The rapid development of the IT sector means that the demand for well-educated network engineers is continuously increasing, and a shortage of specialists may limit the implementation of key technologies, potentially delaying progress across many industries. The use of VR technology for teaching networking solutions can provide tangible benefits, especially when access to physical hardware is limited or associated with high costs.

The second project was created as part of the conducted research in collaboration with industry. An environment was developed to simulate selected tasks performed by network engineers during the installation and configuration of networking equipment, as shown in Figure 2b. The conducted work provided a unique experience in implementing network device stack configurations within a VR environment, along with selected functionalities and networking mechanisms that enable the automation of configuration and administrative processes. The training process flow is presented in Figure 2a.

The step-by-step sequence of actions required within the adopted didactic scenario demonstrates the extensive capabilities of the VR environment. On the one hand, participants have the opportunity to familiarize themselves with the external structure of specific device models, their components, and limitations; on the other hand, they can configure selected administrative tasks. This configuration may involve both network mechanisms dedicated to a single device as well as protocols, mechanisms, and standards that require configuring multiple devices.

In the developed VR training scenarios, participants can work with the latest, often expensive equipment, emulated within a virtual environment. This approach significantly reduces training costs particularly for newly introduced machines, and enables remote education of engineers without requiring travel to specialized training centers.

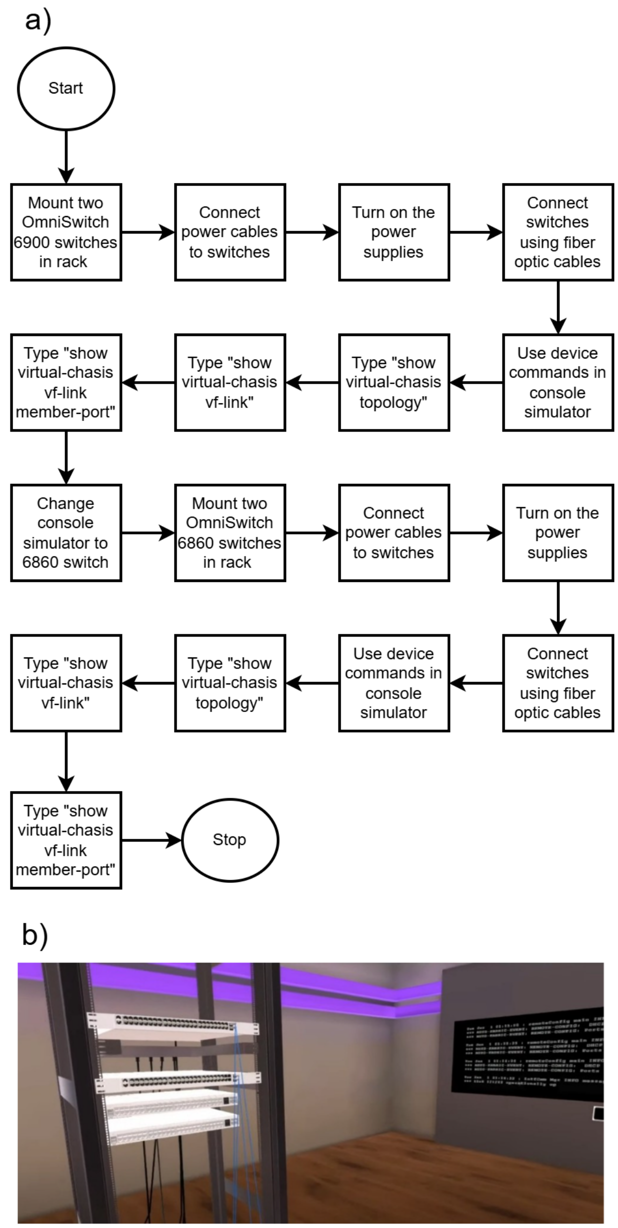

Figure 2: a) Network VR - educational application scenario b) View from the VR system showing a virtual networking workstation configured by the student

3.3 Computer logic and arithmetic training

The final module presented is a VR application that allows students to become familiar with digital electronics. The application view is shown in Figure 3. Within the application, the participant explores topics in the field of:

- Boolean algebra – the fundamentals of digital electronics
- Design and minimization of circuits using Karnaugh maps – a method for optimizing digital circuits
- Multiplexers – designing digital circuits based on multiplexers

Each of the previously described training stages has been separated into individual levels, following the terminology used in video games. The application emphasizes an interactive and accessible approach to knowledge transfer, aiming to increase participant engagement and improve learning effectiveness. A key design principle of the solution is to enable two-person teams to progress through the entire training module by solving tasks related to the topic of each level.

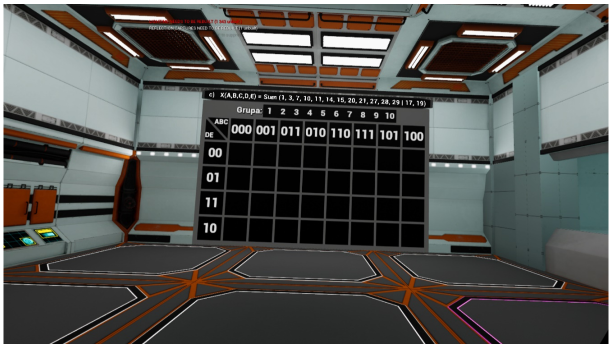

Figure 3: The view of Karnaugh Map in Computer Logic and arithmetic training VR application

Figure 4: The view of Computer Logic and arithmetic training VR application

The exercises are conducted cooperatively. The first participant starts the module by putting on the VR headset and entering the first virtual room, where they receive a task. Their role is to communicate the task content to the second participant, who must solve it outside the virtual environment. After determining the correct answer, the second participant provides it to the first, who inputs it into the VR system. After completing three tasks, the roles are switched, and the second participant takes control of the virtual environment. Upon completing the entire exercise, the application displays a results summary, allowing participants to assess the effectiveness of their performance.

The tasks are divided by difficulty level—exercises 1 and 4, 2 and 5, and 3 and 6 require a similar skill level. Participants cannot progress to the next stage without successfully completing the task at the current level. To ensure the proper flow of the training, a dedicated answer validation system was developed. Additionally, between virtual rooms, participants have the opportunity to take short breaks by performing simple exercises or solving puzzles, allowing for a smooth transition to the next part of the training.

One of the developed modules involves virtual design and fabrication of a selected component, with the entire application set in a narrative context inspired by historical and futuristic themes. Upon launching the application, the user finds themselves aboard a spaceship that has sustained severe damage due to a meteor collision. The starting room is shown in Figure 4. By solving subsequent tasks, the participant gradually restores the ship's full functionality by initializing the power reactor, stabilizing oxygen levels, and repairing the shield and control systems. The introduction of a narrative layer increases user engagement, as the motivation to learn stems not only from the desire to acquire knowledge but also from curiosity and the drive to achieve a goal within an interactive game-like environment.

4 The advantages of XR in Education

The designed VR applications replicate key modules of hands-on activities, allowing students to complete tasks corresponding to real-life teaching scenarios. In the case of CNC machine simulation, the biggest challenge was to create an intuitive interface for selecting instructions - this was solved through a dedicated zoom panel. The web application required a simplified command system, which was realized through ready-made commands and drop-down menus.

Students positively evaluated the tools, indicating an increase in engagement and better absorption of content. VR technology allows learning without access to expensive equipment, while providing a safe environment for trial-and-error learning

5 Conclusion

This article presented the potential of using modern VR technologies in the education and training of highly qualified engineers, technicians, and machine operators. One of the main challenges in specialized training is the limited access to advanced machinery, as well as the need to exclude certain dangerous or niche configuration tasks from the learning process. As a result of the conducted research, several systems were developed and implemented to support specialized education. Three examples of these, along with the underlying instructional methodology, were described in this article.

VR systems dedicated to specific technical solutions require precise representation of real processes, which is associated with a large expenditure of time and resources. It is crucial to take into account technological details so that the VR environment can faithfully reflect operating conditions. Only then is it possible to use VR as an effective tool for testing, training or simulation.

Additionally, virtual training environments allow for the integration of gamification elements into the educational process, which can greatly enhances its effectiveness. Therefore, further research should take into account this aspect and the possibilities and scope of its implementation in training scenarios.

References

[1] Kathya P. Acuña Luna, Edgar Rafael Hernandez-Rios, Victor Valencia, Carlos Trenado, and Christian Peñaloza. 2025. Deep Learning-Enhanced Motor Training: A Hybrid VR and Exoskeleton System for Cognitive–Motor Rehabilitation. *Bioengineering* 12, 4 (March 2025), 331. doi:10.3390/bioengineering12040331

[2] Miroslav Bednar, Patrik Dufek, Alena Lochmannova, Michal Simon, and Marek Bures. 2023. Use of virtual reality for education and training of emergency rescue system for crisis situations. In *The 15th International Conference on Education Technology and Computers*. ACM, Barcelona Spain, 142–147. doi:10.1145/3629296.3629318

[3] Daniela Rocha Bicalho, João Piedade, and João Filipe Matos. 2025. iVRPM: Conceptual Proposal of an Immersive Virtual Reality Pedagogical Model. *Applied Sciences* 15, 4 (Feb. 2025), 2162. doi:10.3390/app15042162

[4] Shijing Cheng and Jiwei Xiao. 2024. Research on the Application of Virtual Reality and Augmented Reality Technologies in Higher Education. In *Proceedings of the 2024 10th International Conference on Frontiers of Educational Technologies*. ACM, Malacca Malaysia, 6–11. doi:10.1145/3678392.3686396

[5] Atsushi Deguchi, Chiaki Hirai, Hideyuki Matsuoka, Taku Nakano, Kohei Oshima, Mitsuharu Tai, and Shigeyuki Tani. 2020. What Is Society 5.0? In *Society 5.0*, Hitachi-UTokyo Laboratory(H-UTokyo Lab.) (Ed.). Springer Singapore, Singapore, 1–23. doi:10.1007/978-981-15-2989-4_1

[6] Johan Ekman, Jordi Solsona, and Luis Quintero. 2024. Codeseum: Learning Introductory Programming Concepts through Virtual Reality Puzzles. In *ACM International Conference on Interactive Media Experiences*. ACM, Stockholm Sweden, 192–200. doi:10.1145/3639701.3656306

[7] Lorenzo Gerini, Giorgio Delzanno, Giovanna Guerrini, Fabio Solari, and Manuela Chessa. 2023. Gamified Virtual Reality for Computational Thinking. In *Proceedings of the 2nd International Workshop on Gamification in Software Development, Verification, and Validation*. ACM, San Francisco CA USA, 13–21. doi:10.1145/3617553.3617886

[8] Ioannis Kavouras, Ioannis Rallis, Emmanuel Sardis, Eftychios Protopapadakis, Anastasios Doulamis, and Nikolaos Doulamis. 2025. Empowering Communities Through Gamified Urban Design Solutions. *Smart Cities* 8, 2 (March 2025), 44. doi:10.3390/smartcities8020044

[9] Silverina Kibat. 2024. Students'Acceptance Towards Technology-Enhanced Learning with Augmented Reality in Sustainable Tourism Education.. In *Proceedings of the 2024 8th International Conference on Education and Multimedia Technology*. ACM, Tokyo Japan, 16–21. doi:10.1145/3678726.3678750

[10] Narmeen Marji, Janset Shawash, Mattia Thibault, and Juho Hamari. 2024. Beyond the Blueprint: Exploring Virtual Reality and Speculative Design in Architectural Pedagogy. In *Proceedings of the 27th International Academic Mindtrek Conference*. ACM, Tampere Finland, 155–167. doi:10.1145/3681716.3681739

[11] Maria Matsangidou, Theodoros Solomou, Cecilie Høegh Langvad, Katerina Xynari, Ersi Papayianni, and Constantinos S. Pattichis. 2023. Virtual Reality Health Education to Prevent Musculoskeletal Disorders and Chronic Low Back Pain in Formal and Informal Caregivers.. In *Adjunct Proceedings of the 31st ACM Conference on User Modeling, Adaptation and Personalization*. ACM, Limassol Cyprus, 343–351. doi:10.1145/3563359.3596991

[12] Mauricio Mojica-Irigoyen, J. Obedt Figueroa-Cavazos, Ana Gabriela Rodriguez-Mendoza, M. Ileana Ruiz-Cantisani, and Vianney Lara-Prieto. 2023. The Effect of a Virtual Reality Resource on the Engagement and Learning Experience of First-year Engineering Students. In *Proceedings of the 7th International Conference on Education and Multimedia Technology*. ACM, Tokyo Japan, 1–7. doi:10.1145/3625704.3625717

[13] Elsa Catalina Olivas Castellanos, Leonel De Gunther, Flor Madalitza Vazquez Paz, Mercedes Trinidad Lerma Ramos, and Oscar David Rivera Garrido. 2022. The Sciences through Pixels: Virtual Reality as an innovation in the learning outcome in higher education in northwestern Mexico: Virtual Reality as an innovation in the learning outcome in higher education in northwestern Mexico. In *Proceedings of the 2022 6th International Conference on Education and E-Learning*. ACM, Yamanashi Japan, 275–280. doi:10.1145/3578837.3578877

[14] Andrzej Paszkiewicz, Mateusz Salach, Paweł Dymora, Marek Bolanowski, Grzegorz Budzik, and Przemysław Kubiak. 2021. Methodology of Implementing Virtual Reality in Education for Industry 4.0. *Sustainability* 13, 9 (April 2021), 5049. doi:10.3390/su13095049

[15] Yoshihiro Shiroishi, Kunio Uchiyama, and Norihiro Suzuki. 2018. Society 5.0: For Human Security and Well-Being. *Computer* 51, 7 (July 2018), 91–95. doi:10.1109/MC.2018.3011041

[16] Nantinee Soodtoetong and Montean Rattanasiriwongwut. 2024. A Virtual Reality Model for STEM Education in Thailand. In *Proceedings of the International Workshop on Artificial Intelligence for Signal, Image Processing and Multimedia*. ACM, Phuket Thailand, 1–7. doi:10.1145/3643487.3662170

[17] Rita Vieira, Patrícia Monteiro, Graça Azevedo, and Jonas Oliveira. 2023. Society 5.0 and Education 5.0 : A Critical Reflection. In *2023 18th Iberian Conference on Information Systems and Technologies (CISTI)*. IEEE, Aveiro, Portugal, 1–6. doi:10.23919/CISTI58278.2023.10211386

[18] Julian Felipe Villada Castillo, Leonardo Bohorquez Santiago, and Sebastian Martínez García. 2025. Optimization of Physics Learning Through Immersive Virtual Reality: A Study on the Efficacy of Serious Games. *Applied Sciences* 15, 6 (March 2025), 3405. doi:10.3390/app15063405

[19] Enes Yigitbas and Janet Mazur. 2024. Augmented and Virtual Reality for Diet and Nutritional Education: A Systematic Literature Review. In *Proceedings of the 17th International Conference on PErvasive Technologies Related to Assistive Environments*. ACM, Crete Greece, 88–97. doi:10.1145/3652037.3652048

[20] Lina Zhong, Weijie Lang, Jia Rong, Guanliang Chen, and Miao Fan. 2025. Enhancing Motivation and Learning in Primary School History Classrooms: The Impact of Virtual Reality. In *Proceedings of the 15th International Learning Analytics and Knowledge Conference*. ACM, Dublin Ireland, 272–282. doi:10.1145/3706468.3706503