11th International Conference of the Immersive Learning Research Network
Practitioner Proceedings iLRN2025

DOI: https://doi.org/10.56198/gq2vv391

MetaIfes: An Immersive Learning Solution for Technical and Higher Education Courses

Ricardo Maroquio Bernardo[1], Edson Maciel Peixoto[1], Mateus de Angeli Almeida[1], Caio Torres Seares[1], Henrique Machado de Oliveira[1], Pedro Lucas Brito Moreira[1] and Lucas Ferri Verzola Mazioli[1]

[1] Federal Institute of Espírito Santo, Cachoeiro de Itapemirim, Brazil
ricardo.maroquio@ifes.edu.br

Abstract. This work-in-progress paper presents MetaIfes, a virtual reality platform designed for students in technical education and higher education courses. The platform aims to deliver immersive experiences across various fields of knowledge. Developed using Unity and C#, the application includes educational modules on topics such as computer assembly, operation of mechanical lathes, geographic exploration, underground mining, cellular biology, and internal combustion engine mechanics, along with features for adding new modules. Tested on Meta Quest 2 and Meta Quest 3S devices, the platform seeks to reduce costs, enhance safety, and increase student engagement in the learning process. This paper discusses the development methodology, expected results, challenges encountered during development, and the potential of MetaIfes to transform educational processes.

Keywords: Virtual Reality (VR), Immersive Learning, Educational Technology, Technical Education, Hands-On Simulation.

1 Introduction

In recent decades, technology has played a crucial role in advancing education, offering new tools and methodologies that improve the teaching-learning process. Virtual reality (VR) stands out as one of these emerging technologies, enabling the creation of immersive environments that foster active and hands-on learning. Recent studies show that VR-based learning environments enhance student motivation and improve knowledge retention by providing interactive and realistic experiences [1].

By combining motivation and knowledge retention through interaction and immersion, VR can spark student interest in schools, teaching methodologies, and the learning process. This, in turn, helps reduce dropout rates and increases indicators of student retention and academic efficiency. [2] support this notion, emphasizing that interactive platforms, such as VR, can significantly contribute to education by decreasing the likelihood of students dropping out, because they create new forms of learning interaction and stimulate students to participate in educational activities.

The emergence of standalone VR devices, such as the Meta Quest series, has significantly transformed the development of accessible and portable educational applications, eliminating the need for high-performance computers. These innovations provide educational institutions with greater flexibility, empowering students to learn anytime and anywhere. Furthermore, the capability to simulate complex scenarios without exposing students to real-world risks makes VR especially valuable for technical and higher education programs, particularly those that rely on hands-on laboratory practices [3].

These diverse possibilities, when integrated into technical and higher education courses, resonate with broader discussions about labor (in both its ontological and economic dimensions), science, and culture, collectively fostering comprehensive human development. Within this framework — designed to integrate and enhance the formative process across all aspects of life — is the concept of MetaIfes.

In summary, MetaIfes was created to address the growing demand for innovative educational solutions. The platform offers a series of educational modules covering key technical knowledge areas, providing a safe, cost-effective, and efficient learning experience. By combining detailed simulations with gamification elements, MetaIfes aims not only to teach theoretical and practical content but also to engage students more effectively [4].

2 Methodology

The development of MetaIfes followed an iterative approach, including phases of design, prototyping, and evaluation. The application was implemented using Unity Personal Edition and programmed in C#. Practical tests were conducted on Meta Quest 2 and Meta Quest 3S devices to ensure a high-quality immersive experience [5,6] when running autonomously on these devices.

Each module was developed based on specific educational objectives, as follows:

a) Computer Assembly: Enable students to simulate the detailed process of assembling a computer, including inserting components, configuring hardware, and troubleshooting.
b) Mechanical Lathe Operation: Facilitate the operation of an industrial mechanical lathe, covering machine setup, execution of turning operations, and safety protocols for tool handling.
c) Geographic Exploration: Allow students to explore geographic regions in a virtual environment, study landforms, and analyze environmental data.
d) Underground Mining: Simulate a realistic underground mining environment where students learn mining techniques, safety procedures, and equipment operation.
e) Cellular Biology: Provide a microscopic exploration experience where students can interact with cellular structures, observe biological processes, and deepen their understanding of cellular functions.
f) Internal Combustion Engine Mechanics: Offer a simplified simulation of an internal combustion engine, enabling students to disassemble and reassemble the engine, understand its components, and learn its operating principles.

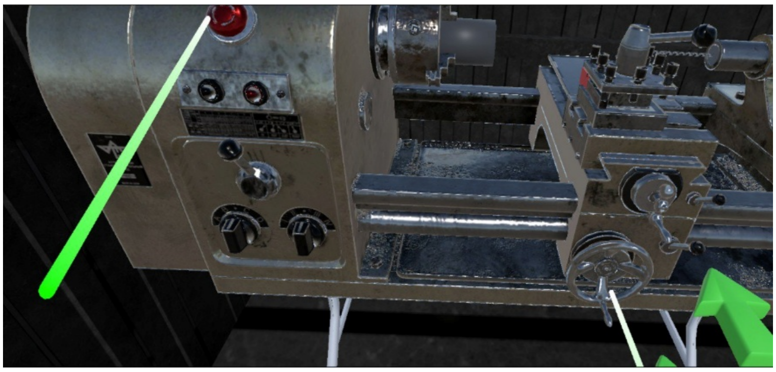

Fig. 1. Mechanical Lathe Module.

Fig. 1 shows the mechanical lathe module. One important aspect to mention is that the module was developed with the assistance of a professional lathe operator, who provided guidance on all virtual operations to ensure accuracy and realism in simulating the processes. This collaboration was essential for replicating real-world lathe functionality and adhering to industry-standard safety protocols.

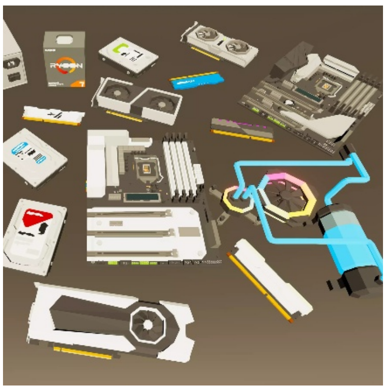

Fig.2. Computer Assembly Module.

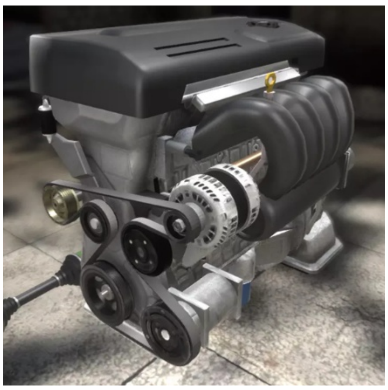

Fig. 3. Combustion Engine Module.

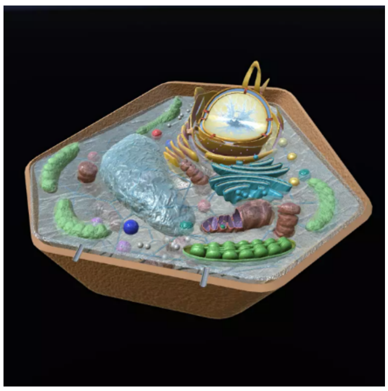

Fig. 4. Cellular Biology Module.

Fig. 2, 3, and 4 showcase others educational modules included in the MetaIfes platform. Fig. 2 illustrates the computer assembly module, where students can interact with various computer components, such as motherboards, CPUs, and memory units, to simulate the process of building and troubleshooting a functional system. Fig. 3 displays the internal combustion engine module, allowing users to disassemble and reassemble engine components, gaining insights into their operation and principles. Finally, Fig. 4 highlights the biological cell module, offering a detailed exploration of cellular structures and processes, enabling students to interact with and observe key biological functions in a virtual environment. These modules are designed to provide immersive and hands-on learning experiences across distinct areas of knowledge.

In addition to interactive simulations, MetaIfes includes text and voice-guided explanations in certain modules, guiding students throughout the learning process and making the experience more accessible and intuitive. These features ensure that key instructions are delivered in real time, simplifying navigation and interaction within virtual environments.

The platform was also designed to support the addition of new modules. To achieve this, core functionalities were implemented to ensure consistency across new applications and reuse of existing resources, including:

a) Teleportation Navigation: Prevents motion sickness by allowing students to move instantly to different points within the scenario.
b) Object Interaction: Supports actions such as grabbing, dragging, and dropping objects, which are essential for practical simulations.
c) Button Pressing: Enables interaction with virtual equipment and selection of options through interactive interfaces.
d) Rigid Body Physics and Collision: Ensures realistic behavior of objects within the virtual environment.
e) Spatial Sound: Provides an immersive audio experience, with sound varying based on the student's position within the scenario.

The development of MetaIfes faced significant performance challenges due to the hardware limitations of standalone VR headsets, requiring the adoption of advanced optimization techniques to ensure a smooth and immersive experience. The following section will discuss these challenges in detail and outline the implemented solutions.

3 Development Challenges

The development of applications for virtual reality headsets poses several challenges, particularly due to the hardware limitations of standalone devices, which have lower computational power compared to high-performance computers. To ensure smooth and immersive experience, several optimization techniques were employed, including:

a) Polygon Reduction: The 3D models and scenarios used in the modules were simplified without compromising visual and functional quality, minimizing the processing load.
b) Optimized Lighting: Static lighting was utilized whenever possible, with lightmaps employed to simulate realistic lighting effects without requiring real-time calculations.
c) Occlusion and Culling: Techniques for occlusion and culling were implemented to avoid processing objects that are not visible to the user at any given moment.
d) Texture Compression: Textures were compressed and resized to maintain good visual quality while reducing memory usage.

These solutions allowed MetaIfes to run effectively on Meta Quest 2 and Meta Quest 3S headsets using only the devices' computational power. As a result, users can experience immersive environments without requiring an external computer, ensuring greater mobility and flexibility in use.

4 Results and Discussion

The initial development of MetaIfes already allows for its full demonstration, although no formal testing has been conducted with specific groups. As a proof of concept, the software was presented at the 2024 National Week of Technical and Vocational Education, generating strong interest among attendees. During the event, dozens of individuals voluntarily participated in a simple virtual computer assembly activity, exploring components such as the motherboard, processor, and memory modules.

The observed enthusiasm suggests significant potential for engagement, aligning with the goal of making learning more immersive and interactive. Participants reported that the experience helped them understand hardware components and their functions, while they also enjoyed working within a virtual reality environment. However, despite the positive feedback, there are no quantitative data yet to confirm effective improvements in performance or knowledge retention. Future studies with more structured designs will be necessary to rigorously evaluate the pedagogical impact of MetaIfes and compare its outcomes with those of traditional teaching methods.

In summary, MetaIfes expected to contribute positively to the educational process in the following aspects:

a) Cost reduction: by offering virtual simulations, the platform reduces the need for expensive physical equipment and materials, making practical training more accessible.
b) Risk reduction: the virtual environment allows students to practice potentially hazardous procedures, such as operating machinery or handling dangerous materials, without real-world risks.
c) Increased engagement: the immersive and interactive nature of the platform is expected to boost student motivation and interest, leading to better learning outcomes [3].
d) Improved understanding of complex concepts: realistic simulations and gamified elements help students visualize and interact with complex concepts, making them easier to understand and retain [1].

5 Evaluation and Future Work

The effectiveness of MetaIfes will be evaluated through practical tests involving students and instructors. Data will be collected on student performance, engagement levels, and satisfaction with the platform. Future plans include expanding the number of available modules to cover additional subjects and incorporating more advanced features, such as personalized learning paths and collaborative learning tools [6]. The long-term goal is to create a comprehensive and versatile platform capable of enhancing education across a wide range of disciplines.

To rigorously assess the educational impact of MetaIfes, we plan to conduct a structured study with approximately 300 participants drawn from technical programs (Mining, Electromechanics, and Informatics) as well as undergraduate courses (Information Systems and Mechanical Engineering). The selection process will aim for a representative sample, considering factors such as age, prior exposure to immersive technologies, and academic performance. Participants will complete pre and post-tests measuring theoretical knowledge and practical skills, supplemented by qualitative feedback (e.g., observation protocols, interviews, and surveys) to capture perceptions of engagement, usability, and learning effectiveness.

A control group receiving only traditional lectures will facilitate a direct comparison of outcomes, shedding light on whether the observed increases in motivation and conceptual understanding can be reliably attributed to the MetaIfes modules. Additionally, we will investigate the nature and prevalence of common misconceptions, particularly those related to complex mechanical or computational concepts, in order to determine how well immersive simulations address these misunderstandings. Collecting individual and group-level data will also enable us to analyze both cognitive and affective dimensions of the learning experience.

To explore the scalability of MetaIfes, we intend to examine its implementation in larger classrooms and different educational levels, including potential adaptations for senior high school and specialized training programs. This examination will consider constraints such as hardware availability and instructor preparation. Future iterations of the platform may incorporate collaborative features, allowing multiple users to interact in shared virtual spaces, and extended analytics to track student progress more comprehensively. Ultimately, these steps will guide refinements to both the software and the instructional strategies underpinning its use, with the goal of solidifying MetaIfes as an effective, flexible tool for immersive education.

References

1. Winn, W., Jackson, R.: Virtual Reality for Conceptual Learning: A Meta-Analysis. Educational Research Review, 18, 78-95 (2021). https://doi.org/10.1016/j.edurev.2021.02.003
2. Tori, R., Hounsell, M. S.: Introduction to Virtual and Augmented Reality (Introdução à Realidade Virtual e Aumentada). In: Tori, R., Hounsell, M. S. (eds.) Porto Alegre: SBC Publishing, pp. 401-421 (2020). https://books-sol.sbc.org.br/index.php/sbc/catalog/view/66/291/540
3. Kavanagh, S., Luxton-Reilly, A., Wuensche, B.: Gamification in Virtual Learning Environments: A Systematic Review. Journal of Educational Technology, 14(3), 45-60 (2022). https://doi.org/10.1016/j.jeduc.2022.01.005
4. Al-Adwan, A. S., Li, N., Al-Adwan, A., Abbasi, G. A., Albelbisi, N. A., Habibi, A.: Extending the Technology Acceptance Model (TAM) to Predict University Students’ Intentions to Use Metaverse-Based Learning Platforms. Education and Information Technologies, 28(11), 15381. Springer Science+Business Media (2023). https://doi.org/10.1007/s10639-023-11816-3
5. Montagud, M., Cernigliaro, G., Arevalillo-Herráez, M., García, M., Segura-García, J., Fernández, S.: Social VR and Multi-party Holographic Communications: Opportunities, Challenges and Impact in the Education and Training Sectors. arXiv (Cornell University) (2022). https://doi.org/10.48550/arxiv.2210.00330
6. Smith, J., Patel, R., Green, T.: Immersive Technologies in Collaborative Learning: Emerging Trends and Applications. Computers & Education, 20(5), 123-140 (2023). https://doi.org/10.1016/j.compedu.2023.04.011