University Students' Perceptions of the Potential of a Metaverse-Based Virtual Learning Environment: An Exploratory Case Study

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Abstract — This exploratory case study investigates university students' perceptions of a metaverse-based virtual learning environment (VLE) implemented on the OnCyber platform as a potential learning tool. Using a mixed-methods approach combining quantitative surveys with qualitative thematic analysis, the study identifies key themes: enhanced learning potential, usability and design challenges, collaboration and communication gaps, and the need for justification and refinement. While many students appreciated the immersive, interactive, and self-paced opportunities offered by diverse media, others encountered issues with navigation, content organization, and technical limitations. These findings underscore the strengths and limitations of metaverse-based education and highlight areas for future refinement.

I. Introduction

In recent years, the concept of the metaverse has garnered considerable attention in the field of Information and Communication Technology (ICT), drawing interest from both industry and academia. The growing importance of the metaverse highlights the need for innovative teaching approaches to effectively convey its capabilities. Initiatives such as the Metaverse Standards Forum Educational Register Working Group [1] exemplify the emerging demand for structured standards in metaverse education. To address this challenge, we created a virtual learning environment in the metaverse, aiming to create an immersive space that fosters a deeper understanding and active engagement with metaverse concepts.

The concept of the metaverse is not new. The term was first introduced in 1992 in the science fiction novel Snow Crash [2,3]. In the novel the metaverse is a massive virtual environment coexisting with the physical world. According to The Wall Street Journal, the metaverse is defined as a ''virtual world where our digital avatars and those of people in our communities and around the globe come together to work, shop, attend classes, pursue hobbies, enjoy social gatherings and more'' [4]. Currently, the term holds the promise of a three-dimensional online environment that is both persistent and immersive. [5], [6].

Users in the metaverse are represented by customable avatars, enabling immersive social interaction [7]. Many metaverse applications, including commercial platforms like Decentraland, utilize blockchain and token economics for avatar customization, trading and voting [8], [9].

The creation of a metaverse environment for education is a relatively novel approach. Previously, [9] designed an interactive campus environment coexisting with The Chinese University of Hong Kong. Approximately a decade and half ago, the fairly popular application Second Life, considered a metaverse precursor, provided a virtual space for users (private, commercial, non-profit) to explore. Several schools and colleges constructed their education facilities within Second Life, offering various courses within this virtual environment. [9,10]

For this study, we created a virtual classroom experiment that allowed students to access the metaverse. The experiment included educational content introducing metaverse technologies and their applications. It was implemented using OnCyber's Metaverse platform which was selected because it had been used earlier for educational uses and was readily accessible. The educational content inside the environment covered technology and non-fungible tokens, business innovations, and practical applications of metaverse technologies. To assess the experiment, we employed mixed methods, including observations, embedded questions in the learning environment, a post-experiment survey, and a follow-up learning task where students were tasked with envisioning potential uses for the metaverse.

The primary goal of this study was to examine learners' perceptions of the metaverse as a learning environment and explore the practical implementation of a metaverse-based virtual learning environment (VLE) on a free, open platform. Specifically, the research assessed how students interacted with the virtual learning space and the challenges or advantages of setting up and utilizing such a platform in an academic setting.

The study analyzed student experiences within the metaverse-based VLE, comparing their perceptions with conventional online learning platforms such as Moodle, Zoom, and Teams. Additionally, it examined the role of multimedia elements such as embedded videos, 3D objects, and interactive exercises in shaping students' learning experiences. Beyond the user perspective, the research also investigated technological and infrastructural challenges related to implementing metaverse-based education in a campus environment, identifying potential obstacles in accessibility, usability, and platform constraints.

The study offers insights into students' overall perceptions of using the metaverse for learning, including their individual learning experiences, engagement in group activities, and the impact of the presence of others in the virtual space. By assessing these factors, the study aimed to provide an understanding of how students interact within a metaverse-based learning environment and to offer recommendations for improving its implementation in higher education settings.

II. Background

This section examines virtual education and how the metaverse is being used to enhance teaching methods and create immersive learning experiences. It begins by defining key concepts related to virtual education and its role within the metaverse. The metaverse is a broad concept that encompasses a variety of digital experiences, while virtual education specifically refers to the use of digital technologies for learning and instruction. Virtual education can exist as part of the metaverse, with educational activities and spaces integrated into its digital environment. Although closely related, "metaverse" and "virtual education" refer to different aspects of the digital landscape. The metaverse is a vast, interconnected digital space that goes beyond virtual and augmented reality, offering various virtual worlds and interactive environments where users can engage with content and each other in real time.

A literature review on the use of the metaverse in education identified Second Life, VRChat, Roblox, Decentraland, Horizon Worlds, and Minecraft as the most popular platforms, none of which are exclusively designed for educational purposes [11]. The metaverse has been found to support collaborative learning environments, fostering teamwork among students and professionals engaged in various projects and assignments [11], [12]. Additionally, it offers potential for developing simulations that allow for in-depth exploration of complex work environments, including tasks such as reengineering layouts, assessing industrial risks, and evaluating equipment eco-efficiency [11].

The metaverse extends beyond education, encompassing social interaction, gaming, and commerce. It integrates digital and physical elements, using technologies like VR, AR, and MR to create immersive experiences. Unlike a single platform, it operates across multiple services in a decentralized manner. Virtual education, as part of online learning, uses digital tools to enhance teaching. It includes virtual classrooms and online courses, leveraging technology for content delivery, interactive engagement, and student assessment.

A. Virtual Education

Virtual education, often termed online learning or e-learning, encompasses diverse educational activities underpinned by digital technology. This research narrows its scope to the metaverse's role within the virtual classroom environment, particularly focusing on the Virtual Learning Environment (VLE) as the primary object of study.

VLEs are integral to this paradigm, encompassing various features that collectively foster a dynamic and effective online educational space. According to [13], VLEs function as social environments, enhancing cooperative and collaborative learning among students through interactive components. These platforms not only serve as hubs for information exchange but also as structured frameworks for organized content delivery. By integrating diverse educational materials in various formats, including text, multimedia, and interactive elements, VLEs facilitate a comprehensive learning experience. Furthermore, they incorporate communication tools, feedback mechanisms, and monitoring features, enabling efficient assessment and evaluation. The resource management within VLEs is streamlined, offering centralized access to learning materials, thus optimizing the educational experience in a virtual realm.

A pedagogical framework for evaluating VLEs has been developed, grounded in both educational and organizational theory [14]. The rise of e-learning and VLEs in the early 20th century was viewed as a way to enhance education and empower learners, a trend that has continued in the following decades [14]. The pedagogical impact of virtual environments, particularly in university training processes, has also been examined, highlighting the significance of VLEs in educational contexts [15].

The pedagogical guidance of Information and Communication Technology (ICT) has been highlighted for its potential to support student-centered learning and foster critical thinking and creativity [16]. However, concerns remain regarding VLEs, including the digital divide and the possible decline in students' social skills [17]. The COVID-19 pandemic further emphasized the importance of virtual education, expanding its role and prompting a reassessment of its impact on stress and anxiety levels [18], [19]. This highlights the need for VLEs that address both educational and social-emotional aspects of learning [20], [19].

Recent studies emphasize the depth of learning experiences and the potential of new environments. The transformation of traditional classrooms into immersive VR scenarios has been identified as a way to enhance research and learning [21]. The metaverse has been recognized for its ability to revolutionize education through interactive and immersive experiences, addressing challenges such as physical accessibility and the need for personalized learning approaches for students with disabilities [22]. The evolving virtual learning environment has also been explored, with a focus on the Metaverse World concept, which integrates Digital Humanities with virtual reality to create a fully connected digital space for diverse users [23].

This study primarily focuses on the positive aspects and benefits of VLEs. They have been recognized as a valuable advancement in education, particularly for their role in improving accessibility and efficiency [17]. Their significance in modern educational settings has also been emphasized, further reinforcing their importance in contemporary learning environments [24].

B. Metaverse in Education

Scholarly interest in integrating metaverse technology into education has grown in recent years, with research exploring its potential as a transformative tool for teaching and learning. A structured framework (Fig. 1) has been proposed to incorporate the metaverse into various educational settings, including blended learning, language learning, competence-based education, and inclusive education [25]. This framework also highlights key challenges, such as the need for innovative educational models, technological infrastructure, and solutions to the digital divide. The metaverse learning environment has been described as a three-dimensional digital space that merges physical and virtual elements, enabling users to interact through avatars, intelligent non-playable characters (NPCs), and virtual learning tools. By removing constraints related to time and location, this space immerses learners in an interactive and dynamic educational setting. [25]

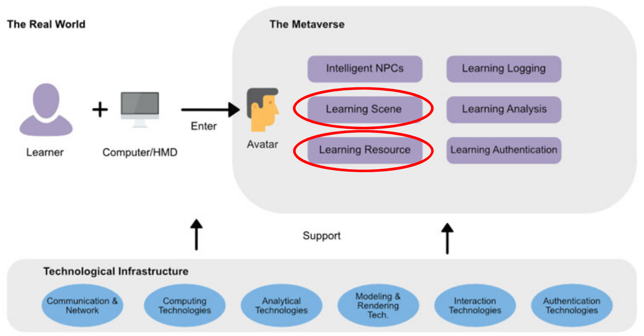


Fig. 1. A framework for education in the metaverse, adopted from [25]

Building on the structured framework for integrating the metaverse into education, this study focuses on two key aspects: learning scenes and learning content, as highlighted in Fig. 1.

In the metaverse, realistic learning scenes can be simulated and created using technologies such as digital twins, VR, AR, and XR [26,9,27,28]. These virtual spaces can replicate real-world classroom layouts or construct entirely new environments tailored to specific learning objectives. For example, 3D-rendered scenes can transport learners to settings that are difficult to experience in real life, such as deep-sea ecosystems, outer space, or historical sites [29,30,31]. Attention to detail, including textures, colors, and ornamentation, further enhances the authenticity of these environments [32]. Institutions have already explored such applications, such as Gathertown, which was used to construct virtual classrooms modeled after real-life learning spaces [33].

The metaverse also enables the visualization of complex or abstract learning content through modeling and rendering technologies [29,34]. These approaches allow learners to physically engage with virtual objects, receive real-time feedback, and experience richer sensory interactions [35,36,37]. For instance, AR has been used to visualize the lunar system in astronomy education, allowing learners to interact with digital representations of celestial bodies [38].

Metaverse systems enable students to practice theoretical knowledge in simulated learning environments at their own pace and in a personalized manner [39]. Research on continuing medical education has shown that students reported improvements in collaborative learning skills, communication, and creativity after using a blended teaching model in the metaverse, compared to traditional online task-based learning [40].

A novel framework for e-learning in the metaverse, known as the ELEM framework, has been introduced for virtual learning environments [41]. This framework consists of three core components: users, devices, and metaverse-specific elements, including infrastructure, avatars, and various metaverse technologies. Designed to foster interactive and intelligent learning experiences, ELEM incorporates digital twin technology, virtual world creation, augmentation, blockchain applications, simulations, and sensory experiences. The framework builds upon existing e-learning models to ensure compatibility while integrating innovative metaverse capabilities.

This study examines how metaverse-based VLEs can create interactive learning environments that go beyond the constraints of traditional classrooms. A key advantage of the metaverse is its decentralized and customizable nature, allowing both educators and students to modify, create, and share content. This flexibility supports collaborative learning, enabling users to shape educational materials in ways that enhance engagement and interactivity.

III. Methodology

This study employs an exploratory case study design, following Yin [42], to examine learners' perceptions of the metaverse as an educational environment. Additionally, it explores the practical implementation of a metaverse-based VLE on a free, open platform, assessing its ease of setup and potential challenges. Exploratory case studies are particularly well-suited for investigating emerging or not yet fully understood phenomena, especially when the boundaries between the research context and the phenomenon itself remain ambiguous.

To investigate the research problem, this study conducted an experimental intervention with first-year undergraduate students in information processing science. The intervention was integrated into a two-hour session within a traditional lecture hall as part of a course on technology innovation and business. To accommodate students who couldn't attend in real time, the metaverse-based learning environment was made accessible afterward. Before the session, students were provided with a selection of academic articles and industry materials, including both written and visual content, to familiarize them with key metaverse concepts.

To evaluate the effectiveness of the intervention, the study used a mixed-methods research approach, combining both quantitative and qualitative data collection. The qualitative data was analyzed using Braun and Clarke's thematic analysis method [43], which provided a structured approach to identifying patterns or themes from the questionnaire answers. Observations were supported by video recordings, screenshots, and traditional notetaking. Short surveys were embedded within the virtual environment, followed by a more detailed post-experiment questionnaire to gather feedback. Multiple observers were present in both the physical and virtual settings to ensure a comprehensive and accurate assessment of the learning experience.

The groundwork for the experiment was built on initial research into virtual learning environments, which helped shape the study's educational framework. The selection of a metaverse platform involved a careful review of various technologies to find the best fit for the experiment's objectives. A pilot phase allowed for refinements before the final implementation, which included an orientation session for students. During this session, feedback was gathered using Mentimeter, while post-experiment responses were collected through Google Forms to support a structured analysis of the experiment's impact. The overall research process is shown in Fig. 2.

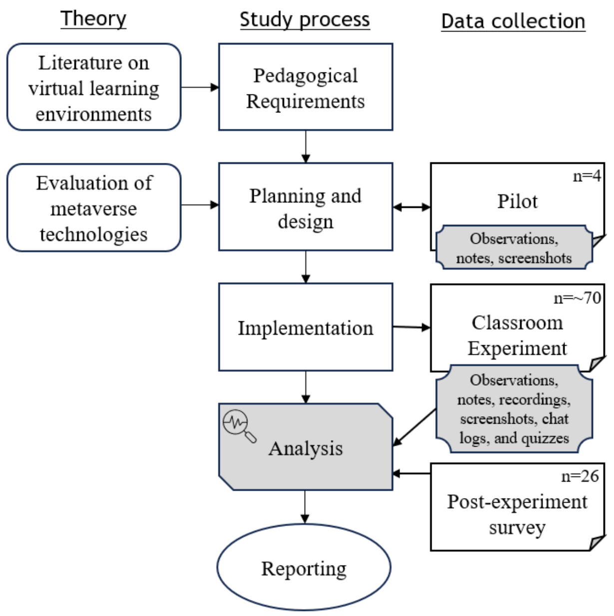


Fig. 2. Study process and data collection

III. Research Settings

This section outlines the methodological framework used to create the metaverse-based learning environment. It begins with an assessment of pedagogical requirements to ensure alignment with educational goals. Next, it details the planning and design strategies behind the virtual space, followed by an explanation of how learning resources were implemented, and the virtual environment was constructed. Finally, it describes the execution of the in-classroom experiment, focusing on the instructional methods and technologies used to support the learning experience.

A. Pedagogical Requirements

In exploring different platforms for the study, OnCyber emerged as the most suitable choice due to its openness and collaborative features. As a browser-based platform, it offered broad device compatibility, eliminating the need for app downloads or complex registration, ensuring easy access for participants. The decision to use OnCyber was influenced by prior experience with the platform through a course at the University of Nicosia. Notably, the university had already developed a virtual space (MetaCampus) for a different purpose and allowed modifications to align with the study's needs, enabling a seamless and efficient integration into the experiment (see Fig. 3). Unlike platforms like Decentraland or VRChat, OnCyber allowed us to construct a tailored experience with minimal overhead and without requiring high-performance hardware or complex onboarding.

Fig. 3. The amphitheater in the University of Nicosia's Meta Campus

B. Planning and Design

The experiment was designed around three key components: spaces, user experience, and surveys. The University of Nicosia provided access to an amphitheater space on the OnCyber platform, which served as a central hub connecting to multiple virtual spaces (see Fig. 4). User experience was a key focus, with in-class group activities assigned by the lecturer and later completed within the metaverse. Surveys were integrated into the experiment, including in-session quizzes and post-session questionnaires to gather participant feedback.

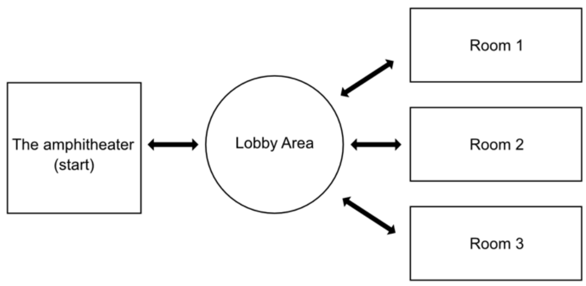


Fig. 4. A simple map of metaverse spaces in the experiment

Each virtual space in the metaverse was designed around a specific learning topic, with different media types integrated throughout. The spatial layout provided a consistent starting point, with pathways leading to other rooms, balancing structured navigation with the open-world nature of the metaverse. Room selection prioritized visual aesthetics and atmosphere, ensuring distinct spaces for different topics. The OnCyber platform offered a range of customizable environments that aligned with the study's objectives. By assigning specific media types to different rooms, the study aimed to explore students' experiences and preferences regarding various learning formats. Virtual spaces were created using pre-existing OnCyber templates, allowing customization through text, images, PowerPoint slides, videos, non-fungible tokens (NFTs), and 3D objects (see Fig. 5).

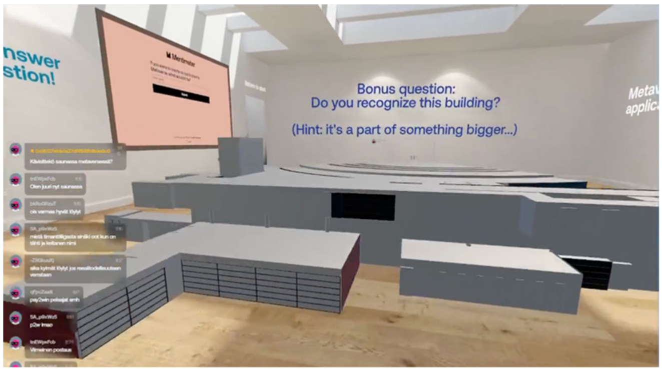


Fig. 5. An example of a 3D object in the space

The user experience design leveraged the unique features of the metaverse, offering a learning environment distinct from traditional online platforms. While digital, the metaverse provided a sense of space and movement, allowing students to navigate between topics as if moving through physical rooms. Since the experiment took place in a physical classroom, sound was excluded, and students communicated via in-session virtual chat. The experience was designed to feel like a digital field trip, aiming to engage students beyond conventional educational methods.

To encourage reflection and collect research data, embedded in-session questionnaires were used (see Fig. 6). Some surveys allowed students to view peer responses after submission, fostering discussion. After the session, students completed a post-experiment survey, beginning with a reflective quiz on learning outcomes, followed by an optional section with research-related questions. Additionally, a learning task connected to the metaverse content provided further insights into students' experiences and perceptions of the platform as an educational tool.

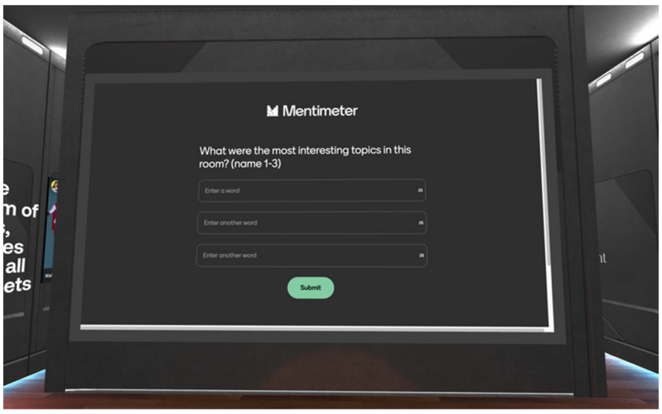


Fig. 6. A room-specific questionnaire within one of the spaces

The learning design focused on two main objectives: fostering direct engagement with the material and encouraging indirect learning through interaction with early-stage technology. This approach aimed not only to support the learning process but also to spark curiosity and exploration.

C. Implementation

Planning and research for the classroom session followed a structured process. The initial script, outlining the research framework and virtual learning environment, was completed on February 20, 2023. Testing took place on February 24, both in the university laboratory and online, to identify technical issues and refine the design.

An English-language pilot was conducted on February 27, during which administrators from the University of Nicosia Meta Campus explored the space. Before this, a portal was added to the amphitheater, linking it to the study's lobby area. The pilot allowed for adjustments based on observations and feedback. Following minor refinements, the Finnish-language version was finalized on March 5 for first-year undergraduate students in a technology innovation and business course.

A key objective was to design a classroom session where the virtual space itself became the subject, providing an immersive learning experience about the metaverse. Learning materials included a mix of original content and openly available online resources. The experiment introduced students to the metaverse at an early stage of its development, offering transparency into its underlying mechanisms. This approach echoed how early computer users interacted with foundational digital tools, in contrast to the seamless experience of modern smartphones. Engaging with an emerging technology provided a deeper understanding of its evolution.

Conceptually, the session functioned as a "field trip" to an emerging digital space, offering students a first-hand look at its possibilities. The virtual rooms covered various aspects of the metaverse, focusing on technology and NFTs, business innovations, and real-world applications, allowing participants to explore the topic from multiple perspectives.

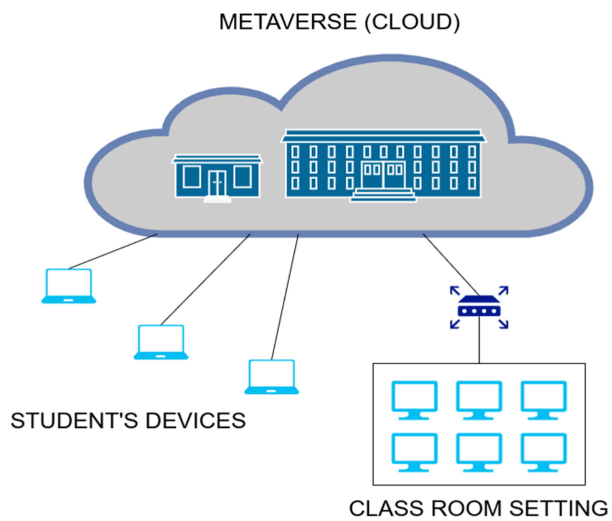


Fig. 7. Network topology for the experiment

In the experiment (see Fig. 7), the educational space within the metaverse was built on a cloud-based network architecture. Network topology refers to the structure of a computer network, including both physical and logical connections between devices. The metaverse served as a centralized platform, hosting the virtual learning environment and related resources on a dedicated cloud server. Students accessed the environment through their personal devices, connecting via the internet, with networking hardware ensuring stable and secure data transmission.

The virtual learning space was composed of interconnected modules designed to function like a showroom or gallery, displaying various educational resources. This setup allowed for scalability and efficient centralized content management. The chosen network topology played a crucial role in the study, supporting the assessment of how metaverse-based learning environments influence student interaction and comprehension.

D. Classroom Experiment Session

The classroom session was structured into four distinct stages:

i. **Orientation:** This initial phase, lasting approximately 15 minutes, involved an in-classroom description of the experiment, guidelines, and its purpose. Additionally, we introduced the learning task that students would complete as assessed coursework after the experiment.

ii. **Tutorial on Using OnCyber's Metaverse:** In the subsequent 10-minute tutorial, students familiarized themselves with the OnCyber platform. They explored the user interface and engaged in several activities including group activities in the metaverse (Fig. 8) that bridged the physical classroom and the metaverse.

iii. **Freeform Exploration of Learning Materials:** Following the tutorial, students had 45 minutes to explore the metaverse within their own space. The environment offered an array of pedagogical resources, including videos, photos, 3D objects, minor tasks, and Mentimeter questionnaires. Participants actively interacted with these materials, engaging in dialogues with peers and instructors via the in-metaverse chat function.

iv. **Completion of the Post-Experiment Survey:** As the exploration time concluded, students transitioned to completing the post-experiment survey.

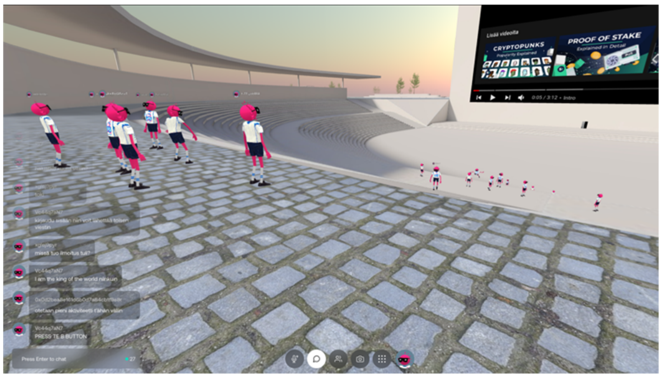


Fig. 8. Students participating in group activities

To participate in the classroom session, students were encouraged to bring their own devices. Additionally, the university provides laptops free of charge for short durations.

V. Results

A mixed-method research approach, combining qualitative and quantitative methods, was used to evaluate the impact of the metaverse-based teaching approach. This methodology allowed for an in-depth assessment of participants' experiences, perceptions, and knowledge acquisition within the virtual classroom. The classroom experiment involved nearly 60 participants, with 26 voluntarily completing a post-experiment questionnaire consisting of 20 questions. Observers were present in both the virtual and physical environments, including designated individuals and the lecturer, who monitored interactions in the classroom.

The post-experiment survey, created using Google Forms, was shared with students via a hyperlink during the session. The first section focused on the session's learning content, while the second addressed the research questions.

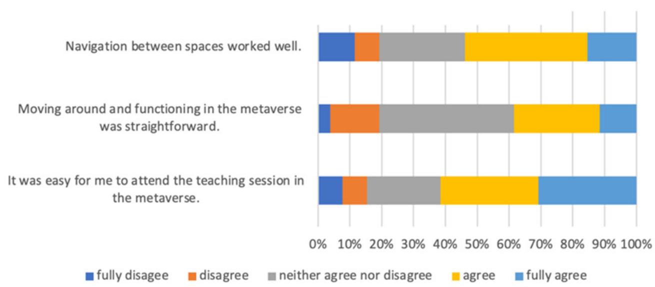
A. Accessibility of the Metaverse Learning Environment

One of the study's objectives was to evaluate the accessibility of the metaverse-based learning environment. Feedback from the post-experiment questionnaire (see Fig. 9) provided insights into participants' experiences with navigation, movement, and overall ease of attending the session in the OnCyber platform.

The results indicate that nearly 60% of participants found navigation between spaces easy, while a notable portion remained neutral. Moving and functioning within the metaverse received mixed responses, with close to half of the participants agreeing it was straightforward, while a considerable proportion expressed neutrality. This suggests that while some found the environment accessible, others may have encountered usability challenges, possibly due to unfamiliarity with the platform or limitations in interactive features.

Attending the instructional session in the metaverse was rated as easy by more than 60% of participants. However, the results also show a notable number of neutral and disagreeing responses, suggesting that factors such as infrastructure limitations (e.g., Wi-Fi connectivity) or individual preferences for traditional learning environments may have influenced the experience. These mixed responses highlight the need for further exploration into how different users interact with metaverse-based learning spaces and the potential barriers they may face.

Fig. 9. Accessibility of the Metaverse Learning Environment.



B. Perceptions of the Metaverse as a Learning Platform

Fig. 10 presents participants' perceptions of the metaverse as a learning platform. The first chart illustrates how participants viewed the metaverse's potential in education. While many participants agreed that it could serve as a learning platform, a significant portion remained neutral, and some expressed skepticism. This variation suggests differing perspectives on the viability of metaverse-based education.

The second chart focuses on the immediate usefulness of the metaverse for learning. Responses were more evenly distributed, with some participants finding it useful, while others remained neutral or disagreed. This suggests that while the metaverse has potential, its current implementation in this study may not have met all learners' expectations. Factors such as content delivery, interactivity, and individual learning preferences could have influenced these responses.

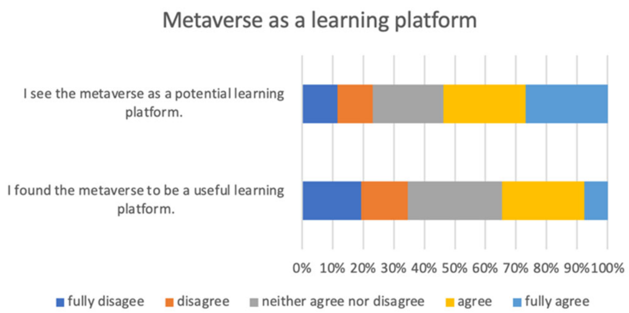


Fig. 10. Perceptions of the metaverse as a learning platform

C. Metaverse as a Platform for Collaboration

Fig. 11 presents participants' views on collaboration within the metaverse and its potential to serve as a platform for fully online courses. The responses indicate a range of perspectives, reflecting both optimism and skepticism regarding its role in education.

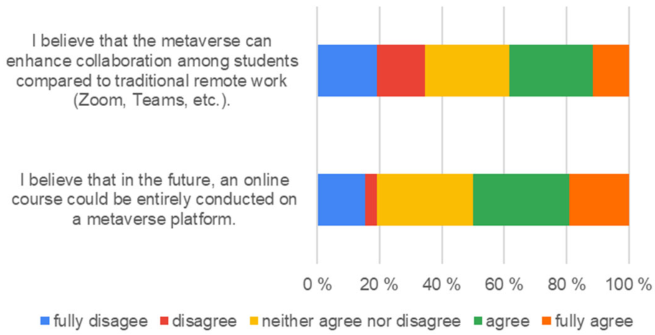


Fig. 11. Metaverse as a platform for collaboration

Regarding collaboration, many participants agreed that the metaverse could enhance student interaction compared to traditional remote platforms like Zoom or Teams. However, a notable portion remained neutral, and a considerable number disagreed. This suggests that while some participants saw potential in the metaverse's interactive and immersive features, others were either unconvinced or encountered limitations that influenced their perceptions. Factors such as usability, familiarity, or platform functionality may have contributed to these varied responses.

On the feasibility of conducting an entire course in the metaverse, responses were similarly divided. While about half of the participants saw potential in this approach, a significant proportion remained neutral or disagreed. This suggests that while the idea of fully metaverse-based courses is appealing to some, concerns regarding practicality, infrastructure, and user experience may need to be addressed before broader adoption is feasible.

D. Individual Learning Experience in the Metaverse

Fig. 12 presents participants' perspectives on individual learning experiences in the metaverse. The responses highlight varying opinions on its effectiveness in supporting learning, its advantages compared to traditional remote education, and the ability to maintain focus during instruction.

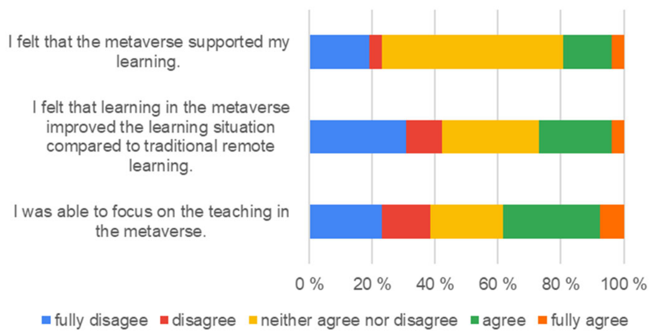


Fig. 12. Individual Learning Experience in the Metaverse.

In the first chart, a large portion of participants remained neutral regarding whether the metaverse supported their learning. A notable percentage disagreed with the statement, indicating skepticism about its role as a facilitator of learning, while a smaller portion found it beneficial. These responses suggest that while some students experienced learning support in the metaverse, many remained uncertain or unconvinced about its effectiveness.

The second chart compares the metaverse-based learning experience to traditional remote learning. The responses are relatively balanced, with some participants agreeing that the metaverse improved their learning situation, while others remained neutral or disagreed. This distribution indicates that opinions on the metaverse's advantages over conventional online platforms vary, potentially influenced by factors such as usability, engagement, or familiarity with the technology.

The third chart explores participants' ability to focus on teaching in the metaverse. Responses were divided, with a similar number of participants agreeing and disagreeing. This variation highlights individual differences in learning preferences, suggesting that while some students found the metaverse conducive to focus, others faced challenges that may have affected their concentration.

Some of the qualitative responses in the survey provide further insight into this topic. When asked, "What were the best features of the metaverse for learning?", students highlighted the variety of media available and noted that the immersive nature of the environment encouraged greater focus on the subject. Several responses also indicated that the novelty of the experience helped maintain interest compared to more traditional online learning tools. Additionally, two students specifically mentioned the ability to go through course materials at their own pace as a positive aspect of the metaverse, drawing comparisons to Moodle, the university's standard online learning platform:

"An interactive way to operate in the environment, self-paced instructional materials, and a "free-world" type of platform, which enabled autonomy."

"The possibility to participate in instruction from anywhere. For example, progressing at one's own pace in an online course is more meaningful than a basic Moodle course."

Fig. 13 illustrates a largely neutral response to collaborative activities within the virtual learning environment, with 46.2% of participants neither agreeing nor disagreeing. Meanwhile, 42.3% expressed disagreement, indicating that they did not find the group activities beneficial for their learning. A smaller portion, 11.5%, found the collaborative tasks to be helpful. These responses suggest varying experiences with group work in the metaverse, with some participants potentially facing challenges in engagement or interaction, while others saw some value in the activities. This can be highly dependent on the metaverse platform in question, as well as the way the contact teaching session was set up.

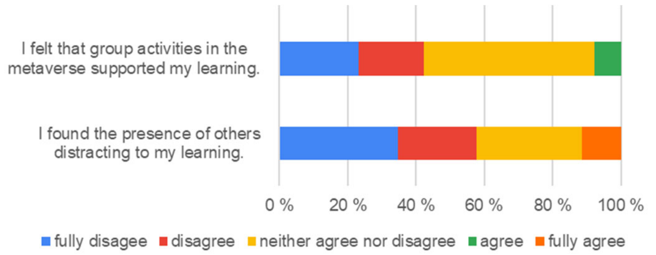


Fig. 13. Group activities and presence of other students in the metaverse

The data indicates that 57.7% of participants did not find the presence of others in the virtual learning environment to be a major distraction, with many actively disagreeing that it was disruptive. Additionally, 30.8% remained neutral on the matter. While some participants noted that social interaction contributed positively to their learning experience, others found it distracting. These mixed responses highlight the varying preferences among learners and suggest that virtual learning environments may benefit from customizable settings that allow individuals to adjust their level of interaction based on their needs.

E. Forms of Media in Metaverse Learning Environment

Fig. 14 presents participants' media preferences in the metaverse learning environment. The media used in different virtual spaces were categorized into three types: embedded videos, text accompanied by photographs, and 3D models. Among these, 42.3% of participants found embedded videos to be the most engaging, suggesting that dynamic and interactive content plays an important role in maintaining student interest. Meanwhile, 26.9% preferred text with photographs, indicating that traditional media formats remain relevant in digital learning environments. Lastly, 30.8% favored 3D models, highlighting the potential of immersive content in metaverse-based education. These findings suggest that incorporating a mix of media formats may be beneficial in accommodating different learning preferences.

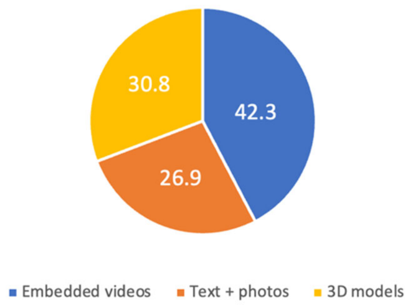


Fig. 14. The division of the preference regarding the various forms of media

The implementation of 3D objects was limited due to constraints in platform functionality and time available for preparing the experiment. Despite this, the 3D elements that were incorporated prompted discussion among participants, as reflected in responses to the survey question: "What content or features does the metaverse need to enhance learning?" Some students emphasized the role of multimodal learning environments, underscoring the importance of integrating diverse media formats to enrich the educational experience:

"Something that specifically requires presentation in a 3D environment, sound, etc., not just presenting traditional classroom material in a new environment."

"Visual elements. For example, computers could be studied in the metaverse if a virtual model or enlargement of the computer could be made. Components could then be examined more closely."

"Voice-based and as natural as possible communication (simulating real-life situations)."

The participants in the study raised a notable concern regarding the graphical fidelity of OnCyber's platform. A considerable number of students expressed dissatisfaction with the suboptimal quality of the visuals. This sentiment is captured by one student's feedback:

"Visually, the metaverse should be at a much higher level to feel like a natural learning environment; crude graphics are too distracting. I learn visually, but currently, the metaverse doesn't offer anything that can't be done better in current online learning environments. Utilizing 3D features in teaching could be a promising area."

Participants expressed a desire for increased interactivity and an expanded repository of learning resources within the metaverse, alongside a more streamlined method of navigating and accessing these resources:

"Clear areas so that learning materials can be found."

"It needs to be more efficient and more easily adoptable than traditional methods."

"More educational content and more interaction."

Furthermore, based on observation and comments from a few students, advertisements in some videos were too distracting. Some of the learning materials linked to YouTube videos directly. This impacted the amount of time spend on those videos.

F. Thematic analysis of the qualitative part of the questionnaire

Out of all the answer to the post-questionnaire, a thematic analysis was conducted. The first and second order themes and the aggregate dimensions can be seen in Fig. 15.

The analysis of the responses provided insights into their experiences with the metaverse as a learning environment. The findings highlight both opportunities and challenges in its implementation, emphasizing four key areas: learning potential, usability and design, collaboration and communication, and the necessity of metaverse-based education.

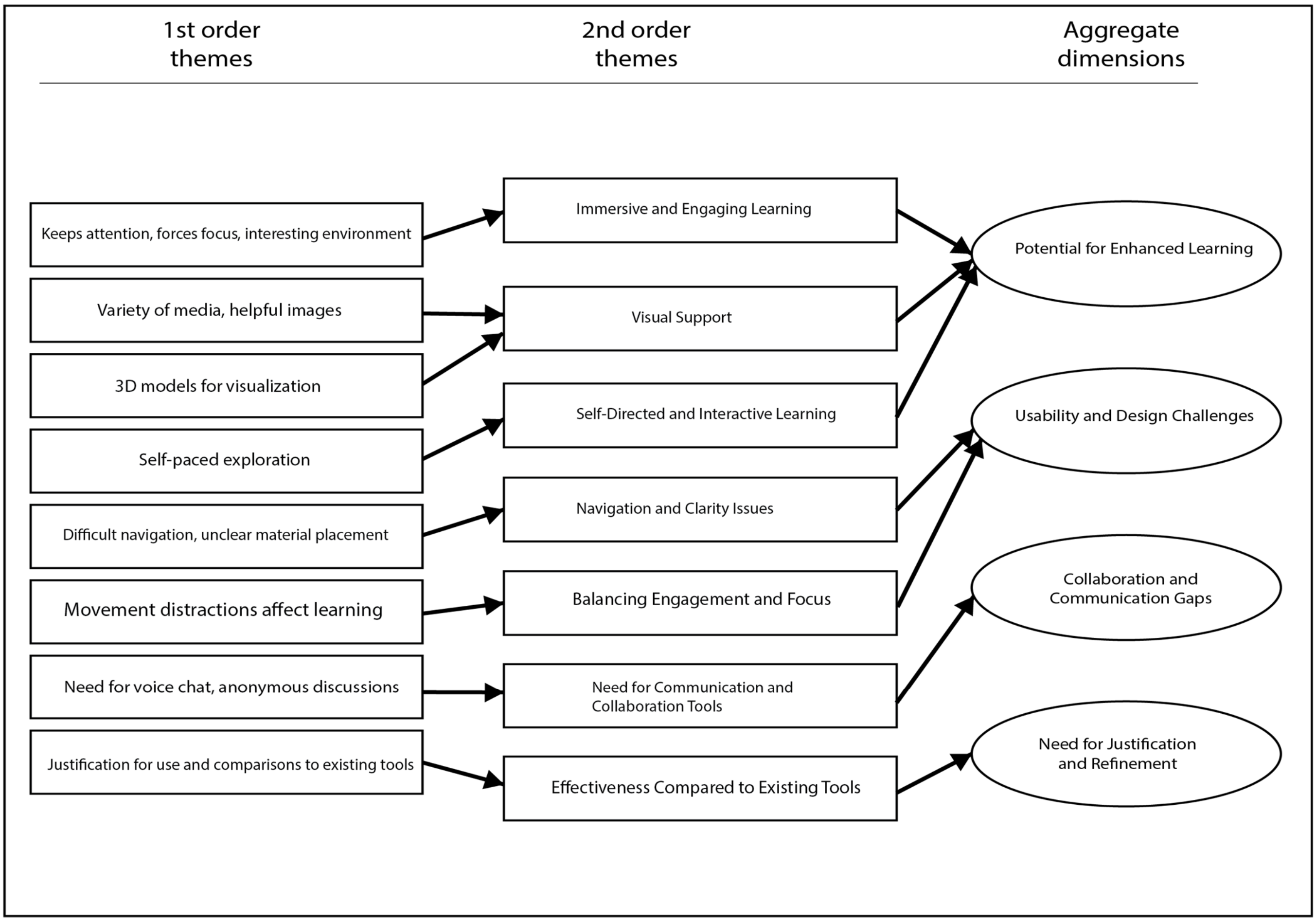


Fig. 15. Results from the thematic analysis

1) Potential for Enhanced Learning

Participants acknowledged that the metaverse introduced new ways of engaging with learning materials, particularly through interactive and immersive elements. The use of 3D models and multimedia content was noted as beneficial for visualization and understanding of complex topics. Some students also indicated that the novelty of the metaverse environment helped sustain their focus compared to traditional online learning tools. However, while engagement was a recurring theme, it was not a universally shared experience, suggesting that the effectiveness of the metaverse as a learning tool may vary depending on individual learning preferences.

2) Usability and Design Challenges

Despite its potential, the metaverse environment presented challenges related to navigation, layout clarity, and overall usability. Several participants expressed difficulty in finding relevant materials within the virtual space, and some felt that movement within the metaverse detracted from their ability to concentrate on learning tasks. Additionally, concerns were raised about the graphical quality and realism of the environment, with some participants suggesting that the current level of visual fidelity made the platform feel less natural as a learning space. These findings indicate that improvements in interface design, content organization, and graphical quality could enhance the overall user experience.

3) Collaboration and Communication Gaps

Another prominent theme was the role of communication and collaboration tools within the metaverse. While some students appreciated the option for anonymous discussions, others highlighted the need for voice-based communication and better support for group work. The responses suggest that interactivity alone is not enough to foster effective collaboration, and without robust communication tools, group activities may not be as effective as intended. Ensuring that future metaverse learning environments provide seamless interaction, real-time collaboration tools, and structured group work features may be crucial for improving engagement in collaborative learning tasks.

4) Need for Justification and Refinement

One of the most critical insights from the analysis was the question of whether the metaverse provides sufficient benefits compared to existing online learning tools. Some participants expressed skepticism about its necessity, noting that many of the same learning activities could be accomplished using traditional platforms such as Moodle or Zoom. Others indicated that, at its current stage, the metaverse did not offer substantial improvements over existing online environments. These perspectives suggest that while the metaverse has potential, it must offer distinct and tangible advantages over conventional learning tools to justify its adoption.

VI. Discussion

Our study set out to explore the potential of metaverse-based VLEs and to identify both their strengths and limitations. Our analysis combined quantitative data and qualitative responses, and the findings are organized under four key aggregated themes: Potential for Enhanced Learning, Usability and Design Challenges, Collaboration and Communication Gaps, and Need for Justification and Refinement.

A. Potential for Enhanced Learning

Quantitative data and qualitative feedback indicate that the metaverse has the potential to create more immersive learning experiences. For example, when asked about media preferences, 42.3% of participants found embedded videos to be engaging, and 30.8% favored interactive 3D models. Qualitative responses further emphasized that the variety of media ranging from dynamic visual content to interactive elements helped maintain focus and fostered an immersive experience. Comments such as "the immersive nature of the environment encouraged greater focus" and the mention of self-paced learning capabilities (as compared to platforms like Moodle) suggest that metaverse-based learning can offer novel ways to engage students and support comprehension. These findings align with the literature that positions the metaverse as an innovative space for interactive, multimedia-rich education [22], [21].

B. Usability and Design Challenges

Accessibility is a critical factor in the success of any virtual learning environment. Our quantitative findings indicate that nearly 60% of participants found navigation between spaces relatively easy, yet a notable number expressed neutrality or encountered difficulties, particularly with movement and material placement. Qualitative comments revealed that while some students appreciated the structured layout, others noted that excessive movement or unclear content organization distracted from learning. This mixed response suggests that despite the metaverse's potential to enhance learning, current usability challenges such as navigation issues, limited graphical fidelity, and suboptimal interface design need to be addressed. These observations are consistent with earlier research calling for improved design and user interface strategies in VLEs [17], [32].

C. Collaboration and Communication Gaps

The metaverse offers unique opportunities for collaborative learning by allowing users to interact in a decentralized, customizable space. Our study's quantitative data on collaboration indicate mixed perceptions. In terms of group activities, 46.2% of participants were neutral, while 42.3% disagreed that group tasks enhanced their learning, and only 11.5% felt they were beneficial. Similarly, responses regarding the presence of others in the virtual space were varied; while 57.7% did not find it distracting, a significant portion remained neutral or disagreed. Qualitative feedback pointed to the need for more natural, voice-based communication and enhanced tools for group work. These findings suggest that while the metaverse holds promise for fostering collaborative learning, its current communication features may be insufficient, echoing concerns in the literature regarding the development of more robust interaction tools [22].

D. Need for Justification and Refinement

A recurring theme throughout the study was a questioning of the metaverse's added value compared to established online learning platforms. Some participants expressed skepticism, noting that traditional tools such as Moodle or Zoom already provided many of the necessary functions for effective learning. Quantitative results on the perceived effectiveness of the metaverse as a learning platform showed a range of responses, with many participants remaining neutral or skeptical about its immediate benefits. Qualitative insights reinforced these concerns, with comments like "why use the metaverse when Zoom works fine?" suggesting that, in its current state, the metaverse might not yet offer sufficient advantages to justify a wholesale shift from conventional methods. This underscores the need for further refinement and technological advancement before the metaverse can be widely adopted as a superior educational tool. These findings align with literature that calls for clear evidence of improved outcomes before new technologies are fully integrated into educational practice [19].

VII. Limitations and future work

This study indicates that metaverse-based VLEs have the potential to enhance learning through immersive, interactive experiences; however, several limitations must be addressed to fully realize this potential. First, the design and implementation of our metaverse classroom were constrained by time limitations during the development phase, which restricted the inclusion of extensive content and interactivity. Additionally, challenges related to technological infrastructure such as inconsistent Wi-Fi access and bandwidth limitation in the classroom and inherent limitations of the OnCyber platform hindered the execution of the virtual environment, particularly in embedding advanced features and interactive elements.

Moreover, our findings reveal that usability and communication remain critical challenges. Future work must focus on iterative improvements in platform design and functionality, including the development of more effective, voice-based communication tools and a clearer justification for transitioning from traditional online platforms. Enhancing the technical infrastructure that supports metaverse-based education is also essential to ensure a seamless and effective virtual classroom experience.

Building on the insights gained from this initial experiment, subsequent studies in the same university course have adopted more rigorous research designs and methodologies. Our ongoing and future research now incorporates more immersive, VR-based experiments, which aim to address the current limitations by leveraging improved technology and pedagogical strategies. These efforts will further explore the distinct benefits of metaverse-based learning and determine the conditions under which it can be most effectively implemented in diverse educational settings.

VIII. Conclusion

This study set out to evaluate the potential of metaverse-based virtual learning environments (VLEs) to enhance educational experiences and to assess their practical implementation. The VLE was developed using the OnCyber platform which is a browser-based environment that allowed for rapid access and customization. By modifying pre-existing room templates, the research team created multiple interconnected virtual spaces that simulated realistic learning scenes, incorporated interactive media, and integrated immersive 3D models.

Our mixed-methods approach, combining quantitative survey data with qualitative thematic analysis, revealed a complex picture. On one hand, the metaverse demonstrated promise in providing immersive and engaging learning experiences, particularly through its capacity to integrate diverse media formats and support self-paced, interactive learning. On the other hand, the study identified significant challenges in usability, navigation, and communication—issues that were evident both in the quantitative data and qualitative feedback.

Moreover, while the decentralized and customizable nature of the metaverse was recognized as a key advantage, several participants questioned its added value compared to established online platforms like Moodle and Zoom. These mixed perceptions underscore the need for further refinement in platform functionality and pedagogical integration.

In summary, metaverse-based VLEs hold considerable potential to transform virtual education. However, their successful implementation will depend on addressing usability challenges, enhancing communication tools, and clearly demonstrating educational benefits beyond existing methods. Future research should focus on iterative design improvements and robust comparative evaluations to better understand the conditions under which the metaverse can effectively meet the diverse needs of learners.

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While not directly participating in the undertaking, OnCyber's metaverse platform, with its ease of use and existing tools for easily adding content in virtual spaces, was critical in creating the virtual learning environment in such a short period of time.

We would also want to extend our thanks to our willing participants in the university class for contributing to the research.

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