Remodeling a Mobile Educational Metaverse Using a Co-Design Approach: Challenges, Issues, and Expected Features

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ABSTRACT

The emergence of the metaverse has expanded the vital role of virtual worlds in education. It extends the traditional configuration of virtual spaces by offering a more immersive, interactive, and social experience. Unfortunately, there is insufficient literature on how to develop a metaverse application aligned with academic standards and best practices. In this study, we adopted a co-design approach in remodeling our mobile educational metaverse to draw a blueprint for existing and future metaverse technology adopters. We sent a follow-up survey to stakeholders inviting free-text comments. This survey focused on the challenges, issues, and expected features from the perspectives of developers, teachers, and students, respectively. Our results revealed several challenges that developers face when building a metaverse, such as technical infrastructure, student engagement, avatar customization, and performance optimization. Meanwhile, teachers emphasized potential issues that may arise from the use of metaverse technology in educational settings, such as learning outcomes, health and safety, digital citizenship, and ethics and morality. Finally, students expected several key features of an educational metaverse application, such as socialization and collaboration, virtual world interactions, metaverse optimization, realistic graphics, and minigames and activities. The implications of these findings are significant and can help other educational institutions seeking to integrate metaverse technology into their academic services. Overall, our study presents an initial foundation for further exploration and advancement within the rapidly evolving field of metaverse technology.

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CCS CONCEPTS

• **Human-centered computing** → Human computer interaction (HCI); HCI design and evaluation methods; Usability testing; • **Applied computing** → Education; Interactive learning environments.

KEYWORDS

Metaverse, Higher Education, Co-Design, Interactive Learning, Mobile Technology

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1 INTRODUCTION

What if you could step into a fully immersive digital realm where you can work, learn, socialize, and meet people from around the globe? This is the foundational concept of the metaverse – a term coined by science fiction author Neal Stephenson in his 1992 novel *Snow Crash*. According to a systematic review [1], the metaverse can be defined as a three-dimensional (3D) digital space that is separate and distinct from the physical world. It was once an illusory space until recent technological advancements made it possible to converge physical and cyber worlds [2-4]. Since then, it has captured the imagination of both academic and industry circles as the idea of a parallel universe in a digital realm that transcends the limitations of physical reality becomes increasingly feasible. Recognizing its potential as a transformative platform, numerous sectors of society have started to explore this emerging technology. Some examples include agriculture [5], tourism [6], marketing [7], healthcare [8], education [9], and even politics [10]. As we continue to push the boundaries of what is possible within the metaverse, this technology will continue to offer new and exciting opportunities for social, economic, and cultural activities in a fully immersive and interconnected digital environment [11-14]. This prospect has inspired this study to explore the potential of metaverse technology and the concept of virtual worlds in the field of education.

Recently, it has become increasingly clear that virtual space has a prominent role to play in education. For example, numerous educational institutions offer courses exclusively delivered through

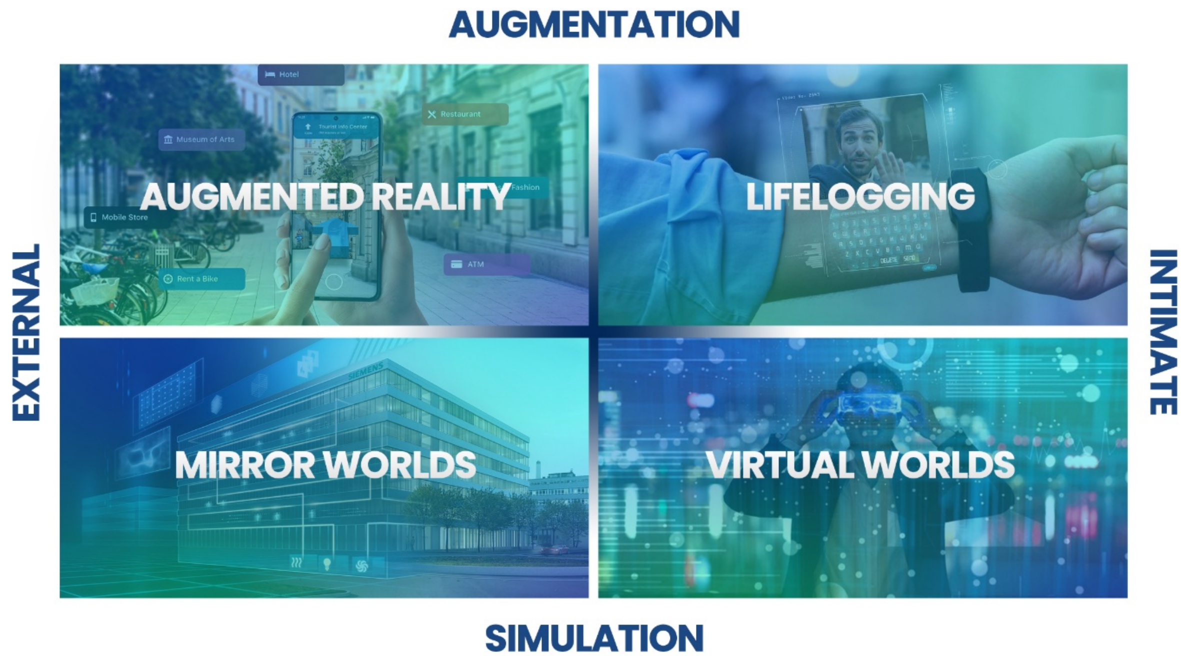

Figure 1: Four Types of Metaverse.

online platforms. The COVID-19 pandemic has even accelerated its integration into educational practices and curricula [15-18]. This mode highlights the growing importance of virtual spaces as a platform for providing education, which can complement or even replace traditional classroom-based learning. In this context, virtual space refers to a digital environment where learners and educators can interact and engage in various educational activities. It can take many forms, including digital classrooms [19], online learning systems [20], and other computer-assisted instruction [21]. The metaverse extends the traditional configuration of these virtual spaces by offering a more immersive, interactive, and social experience. This distinction is evident in the comparison between three educational models: traditional, online, and metaverse [22]. Accordingly, there are seven ways the metaverse can have a positive impact on education: immersive interactive experience, visualization, low learning costs, unrestricted time and space, academic misconduct prevention, personalization, and the promotion of communication. These potential benefits solidify the necessity to build an educational metaverse.

Building a metaverse is a complex undertaking that involves integrating various technologies to form a cohesive virtual environment. Indeed, the evolution of computer technologies has made it possible for the metaverse to transition from a mere science fiction concept to a plausible reality. Some of these advancements include the Internet of Things [2], virtual reality [23], non-fungible tokens [24], blockchain [25], machine learning [26], big data [27], and artificial intelligence [28]. Despite these many technologies, people often associate metaverse with virtual reality (VR) and augmented reality (AR). In a bibliometric analysis [29], VR and AR are some of the most used technologies for a metaverse application in education. A plausible explanation is that these technologies enable users to immerse themselves in a simulated environment and interact with a digital world in a way that closely resembles real-life scenarios. This level of immersion and interactivity is a central aspect of the metaverse, where users can engage with each other and the virtual environment in a shared space. However, it is important to note that the metaverse is not limited to a certain technology as it encompasses a broad range of virtual experiences. As shown in Figure 1, metaverse applications can be classified into four categories: augmented reality, lifelogging, mirror world, and virtual world. Among these classifications, lifelogging and mirror world applications are comparatively less commonly utilized in the metaverse literature [29]. This research gap was addressed by developing a mobile-based educational metaverse called MILES Virtual World [30].

MILES Virtual World is a 3D avatar-driven non-VR metaverse-inspired digital school environment designed to mirror the physical world of academia. In this project, we defined a non-VR metaverse as a digital world that is accessible and navigable through a mobile device. It possesses the same characteristics as the VR-based metaverse, particularly from a mirror world taxonomy, but without the restriction of a VR headset. Among other things, the lack of research on metaverse applications without the restriction of any technology inspired our research project. Despite successfully developing the first version of MILES Virtual World, it was evident from a series of beta tests that several areas for improvement must be addressed. Therefore, we adopted a co-design approach to actively involve stakeholders in the reconceptualization process. This human-centered design methodology enlists end-users as active actors in the design process and recognizes the value of their perspectives and experiences. Numerous investigations have already employed students, teachers, and other stakeholders as co-designers of educational interventions, curricula, and learning resources [e.g., 31, 32-34]. In addition to existing empirical evidence on the effectiveness of this participatory design, it is also the most appropriate approach to answer the following research questions (RQ) of this study:

- What challenges do developers confront in building a metaverse?
- What issues do teachers foresee concerning the metaverse use in education?
- What key features do students expect in an educational metaverse application?

Our primary goal is to draw a blueprint for existing and future metaverse technology adopters on how to build a virtual realm tailored for educational experiences. As the builders themselves, developers possess specialized technical expertise and knowledge that is critical to the successful development of metaverse technology (RQ1). Recognizing the challenges that they face can inspire innovation and creativity in the development of new solutions. As someone with specialized knowledge and experience in teaching and learning, teachers have a unique perspective on the context in which the metaverse application will be used (RQ2). Identifying the issues that they think are worth addressing will ensure that the application aligns with educational standards and best practices. As the primary end-users, students can pinpoint the specific features and functionalities that are most beneficial for them (RQ3). Incorporating these elements can help to increase the adoption and utilization of the technology. Overall, co-designing with these stakeholders can encourage a collaborative approach to the design and development processes, where multiple perspectives are embedded into the final product. We expect that this approach can lead not only to a more effective MILES Virtual World but also to the creation of a roadmap for other educational institutions seeking to build their respective metaverse applications.

2 METHODS

2.1 Research Design

This study adopted a qualitative approach and a co-design process that involves teachers, students, and developers in remodeling a mobile educational metaverse application. A qualitative approach is particularly suitable for conducting an in-depth investigation of complex and intricate phenomena [35, 36], such as metaverse experiences [37]. As co-design studies often involve multiple stakeholders with different viewpoints, this research method can ensure the extraction of diverse perspectives. In the case of co-design methodology, to our knowledge, our study is the first to use it in a metaverse context. One possible reason is the complexity of this new technology and the expertise required to build an entirely new virtual world. These barriers present significant challenges for non-experts to contribute meaningfully to the design process. Consequently, our strategy to mitigate these obstacles was to divide the facets of the phenomenon among the various stakeholders involved in the design process: challenges in building a metaverse for developers (RQ1), issues concerning metaverse use for teachers (RQ2), and key features of the metaverse application for students (RQ3).

2.2 Setting and Sample

This study was carried out at FEU Institute of Technology (FEU Tech) in the City of Manila, Philippines. During the COVID-19 pandemic, the university initiated the Mastery-based Individualized Learning Enhancement System (MILES) program that aims to provide adaptive learning experiences for students to achieve mastery of the subject matter at their own pace. Since then, the initiative has expanded its efforts by developing more educational technologies that support the teaching and learning process. Some examples include MILES Network Map, MILES Credentials, and MILES Virtual World. The concept behind MILES Virtual World started simply as a playable 3D virtual tour (i.e., MILES Virtual Tour) designed to offer an interactive campus visit experience to prospective students. All these innovative technologies were exclusively created for FEU Tech. Therefore, participants were recruited from the university, except for some external developers, to meet the data saturation protocol. A total of eight teachers, nineteen students, and six developers participated in the study (n = 33).

2.3 Procedure and Data Analysis

As explained in previous studies [30, 38], we conducted a series of beta tests as part of our co-design approach. These beta tests serve as the primary procedure to evaluate the current version of the application as well as prepare for future installments. Using the research questions as the basis of the instrument, we sent a follow-up survey to stakeholders inviting free-text comments. This decision was an attempt to look at the project from a macro perspective before the grand launch of MILES Virtual World. Notwithstanding the limitations associated with free-text comments, they can still be used to identify issues that hold significance to stakeholders but were not encompassed in our earlier evaluations [39]. It is also a more cost-effective way to gather feedback compared to interviews. We conducted a thematic analysis to analyze these responses using the guidelines outlined in a recent study [40]. ‘It is composed of six steps: (1) familiarizing the data, (2) generating initial codes, (3) searching for themes, (4) reviewing themes, (5) defining and naming themes, and (6) producing the manuscript. Given the small number of participants, we decided to perform the analysis manually.

3 RESULTS

3.1 RQ1: What challenges do developers confront in building a metaverse?

Developers possess critical insights into the technical challenges involved in building a metaverse. Their experiences in developing the application may serve as a valuable source of information, especially for other creators and metaverse adopters. In our co-design evaluation with developers, they listed the following challenges: technical infrastructure, student engagement, avatar customization, and performance optimization.

3.1.1 *Technical Infrastructure.*

The most prevalent challenge mentioned by the developers is the necessity for a scalable and robust technical infrastructure. This barrier is primarily driven by the complex and interconnected nature of the metaverse ecosystem. They compared the metaverse application to an online multiplayer

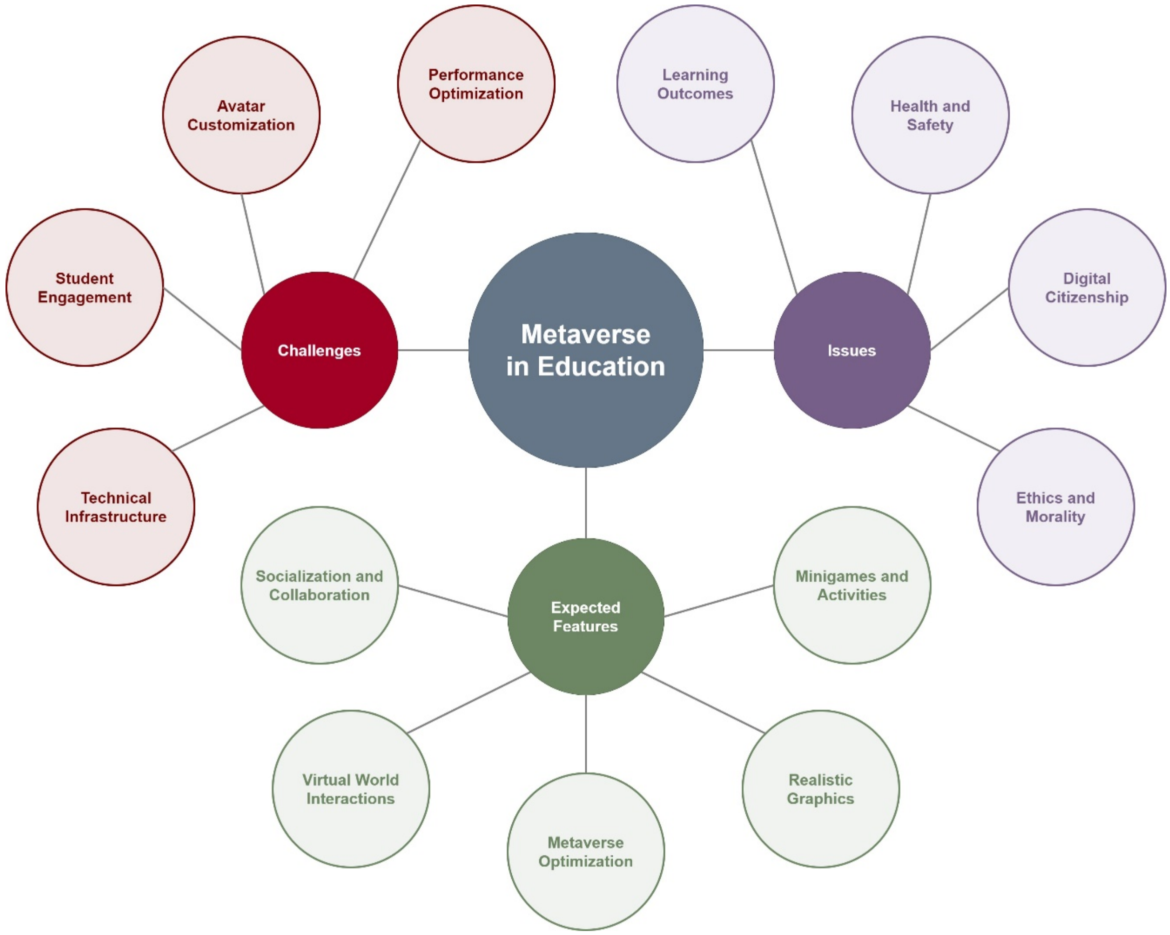

Figure 2: Challenges, Issues, and Expected Features.

video game and specifically mentioned the requirements for stable servers that can handle many students. Some of them said:

> "*With thousands of students, our app will surely require high computational power.*" - [D2]

> "*We were only able to stress test the server with less than 200 students so we do not know yet how it will hold when thousands of students enter the metaverse at the same time.*" - [D4]

> "*We treat the application as an MMORPG, so we definitely need a stable server to host our app.*" - [D5]

3.1.2 Student Engagement. Like other educational applications and information systems, creating a compelling and engaging virtual world is a complex task that requires a deep understanding of user behavior, psychology, and preferences. Developers acknowledged the importance of having engaged users as they are more likely to become active members of the metaverse community who contribute to its growth and sustainability over time. Some of them stated:

> "*I think it's essential to continuously add digital activities to keep users engaged and excited.*" - [D1]

> "*Still, I believe our success comes down to creating something that students will find enjoyable.*" - [D3]

> "*It's all about making the application that students will enjoy coming back to time and time again. As repeatedly said by Dr. Garcia, we must incorporate the elements of cooperation and competition.*" - [D4]

3.1.3 Avatar Customization. Avatars are often the primary representation of the user's identity within the virtual world, just as their physical appearance is a representation of their identity in the real world. Although developers recognized the significance of offering users a wide range of customization options that accurately reflect their personalities and preferences, they asserted that it is difficult to achieve photorealistic 3D customizable models. They noted:

> "*Creating realistic avatars and allowing students to customize them is my biggest challenge, especially since it involves modeling the face correctly and adding the correct textures and lighting.*" - [D4]

> "*It is easier if students will just choose their avatars than customizing them to look like them.*" - [D5]

"*We like to imitate the character customization in GTA V, but it is challenging to do so.*" - [D6]

3.1.4 *Performance Optimization.*

Given the complexity of a metaverse that entails diverse user interactions and functionalities, it is anticipated that the application would necessitate a substantial allocation of computational resources. Developers recognized optimization as an essential process in building a metaverse. Through optimization, developers can not only ensure the efficient operation of the application but also reduce its installation file size. Some of them stated:

"*I am currently remodeling all 3D assets to reduce the polycounts while maintaining realism.*" - [D2]

"*We are trying our best to reduce the installation file since the initial installer was 1.5 GB. We just applied a strategy where students will be asked for additional downloads only when they need them.*" - [D4]

"*Game developers must optimize the app so it will not lag especially to those with low-end devices*" - [D5]

3.2 RQ2: What issues do teachers foresee concerning the metaverse use in education?

Teachers play a crucial role in the successful implementation of new technologies in the classroom. Their perspectives and insights are essential in ensuring these technologies are effectively integrated into the teaching and learning process. In our co-design evaluation with teachers, they expressed their concerns on the following issues: learning outcomes, health and safety, digital citizenship, and ethics and morality.

3.2.1 *Learning Outcomes.*

Unsurprisingly, teachers prioritize the potential impact of metaverse use on the learning outcomes of their students. Despite the overwhelming literature on virtual learning environments, the empirical evidence on metaverse is still insufficient. As a result, teachers may worry that incorporating metaverse technology into their curriculum may not lead to the desired improvements in student learning. Some of the teachers said:

"*This is a new technology so I am not sure whether it will help or hinder my students in school.*" - [T2]

"*We must ensure that this kind of game will not be a distraction but a useful educational tool.*" - [T4]

"*MILES Virtual World should be designed in such a way that it assists us teachers in our lessons.*" - [T7]

3.2.2 *Health and Safety.*

Teachers also expressed their concerns regarding the health and safety implications of using metaverse. The immersive nature of the technology led them to believe that it can lead to prolonged periods of screen time, which can be detrimental to students' health. Moreover, they expressed reservations about the prevalence of cyberbullying, which has become increasingly prevalent in the contemporary digital era. Some of them stated:

"*The developers must be proactive in monitoring potential cyberbullying in the virtual world*" - [T5]

"*I worry that students may spend too much time playing that it could affect their physical health.*" - [T6]

"*We can monitor students in the physical world and there should also be someone in the metaverse.*" - [T8]

3.2.3 *Digital Citizenship.*

The responsible use of metaverse by students, especially when interacting with other users, has also emerged as a pressing issue. Teachers emphasized the importance of online etiquette to avert inappropriate conduct that may lead to negative social and academic consequences. They also stressed the necessity for students to be mindful of their actions and maintain a positive and safe virtual environment. Several teachers said:

"*We need to remind students to be considerate when interacting with others in the virtual world.*" - [T1]

"*There should be guidelines that everyone should follow when using the application.* " - [T5]

"*Our number one priority should be a safe virtual environment for everyone.*" - [T8]

3.2.4 *Ethics and Morality.*

Teachers believe that ethics and morality can also be a source of conflict in the metaverse due to the significant level of autonomy that users possess. They likewise emphasized that the anonymity and distance provided by the virtual realm can lead to a lack of accountability for one's actions, making it easier for students to engage in unethical or inappropriate behavior without fully realizing the consequences. Some of them noted:

"*One thing that worries me is how easy it is to commit unethical behavior behind the screen.*" - [T2]

"*We need to make sure that our students understand that there are real-world consequences for their actions in the metaverse so they should behave the same way they do in the physical world.*" - [T4]

"*It's important to have an orientation with students on how they socialize in the virtual world.*" - [T5]

3.3 RQ3: What key features do students expect in an educational metaverse application?

As the primary target users of MILES Virtual World, we believe that students can help identify the specific features that would enhance their metaverse experience. Involving them in the design process ensures that our educational metaverse application aligns with the end-users' priorities, rather than relying on assumptions. In our co-design evaluation with students, they expected the following features: socialization and collaboration, virtual world interactions, metaverse optimization, realistic graphics, and minigames and activities.

3.3.1 *Socialization and Collaboration.*

As a virtual space where people can interact with one another, the metaverse is viewed as a platform for socialization and collaboration. Students asserted that the application should enable them to build relationships, establish support systems, and develop a sense of belonging. They believed that it should provide them opportunities to connect with other students from different campuses of their university. Several students stated:

"*It would be cool if we could indeed connect with my fellow tamaraws from other schools.*" - [S2]

> “*My expected feature will be the capability to talk with other students and do activities together.*” - [S5]
>
> “*I think it would be awesome if we could have virtual study groups in the MILES Virtual World.*” - [S12]

3.3.2 Virtual World Interactions. Interaction with the virtual world and all objects within can allow users to have a more immersive metaverse experience. Students agreed with this assertion as they prefer to have the ability to interact and manipulate virtual objects in the digital realm. They asserted that having this feature can simulate real-world scenarios and provide them with a practical learning experience that can prepare them for real-world situations. They stated:

> “*Moving around is not enough. We should be able to interact with all objects just like in real life.*” - [S11]
>
> “*My avatar can sit in the chair in the computer laboratory, but I cannot use the computers.*” - [S14]
>
> “*More interaction to the environment or the world like being able to use the objects in the game.*” - [S15]

3.3.3 Metaverse Optimization. As stated by the developers, optimizing the application poses a major challenge for them. Thus, it is not surprising that many students have noticed the necessity of this process. They argued that optimizing the application is essential to ensure that they can have an immersive experience in the virtual world. More importantly, some students were unable to access the application due to their device’s low specifications. Some students said:

> “*The game size is too big for how it looks and it’s way bigger than the games I know.*” - [S5]
>
> “*Optimize the application so we can have faster loading time and smaller file size.*” - [S7]
>
> “*Please optimize the game more since one of my classmates was not able to play on her device.*” - [S8]

3.3.4 Realistic Graphics. Having realistic graphics provides a heightened sense of presence and realism, making the metaverse more engaging and stimulating. This metaverse characteristic is challenging since high graphics are correlated to the application size. Nevertheless, students recommended the use of high-resolution textures, detailed models, realistic lighting, and shading effects to create a more believable virtual world. Several students stated:

> “*Balancing its graphical fidelity to keep it visually appealing as well as the resources needed to run it.*” - [S5]
>
> “*My request is to make the 3D models like in real life with realistic textures and lighting.*” - [S10]
>
> “*I feel like the graphics lack the needed textures that make it look flat and without depth.*” - [S14]

3.3.5 Minigames and Activities. The inclusion of many minigames in the application was a popular request among students. Based on their feedback, minigames can offer a form of entertainment that is distinct from the core functionality of the metaverse application. Meanwhile, having different activities provides a sense of diversity in the experience and prevents them from feeling monotonous while in the virtual world. Several students stated:

> “*I would request different kinds of minigames such as sports games to make it more entertaining.*” - [S9]
>
> “*Maybe sports activities when you are in the school gym or participate in different events.*” - [S11]
>
> “*Any minigame would be fun as long as winning the said games could be valuable in the real world.*” - [S17]

4 CONCLUSION AND IMPLICATIONS

The evolution of computer technologies has enabled the metaverse to transition from a science fiction concept to a plausible reality. Its emergence has significantly expanded the vital role of virtual worlds in education. Unfortunately, the literature has not comprehensively covered all types of the metaverse, with a particular research gap on the lifelogging and mirror worlds. Understanding the potential of these metaverse technologies can lead to the development of innovative educational tools that enable students to engage with the virtual world in new and exciting ways. Meanwhile, many metaverse applications are reliant on specific technologies (e.g., virtual reality headsets). While these devices offer a highly immersive and interactive experience, they also pose a significant barrier to access for users who may not have access to the necessary hardware. We addressed these research gaps and limitations in our preliminary development of the MILES Virtual World application.

Despite successfully developing its initial version, we discovered through a series of beta tests that several areas for improvement must be addressed. Subsequently, we sent a follow-up survey to stakeholders inviting free-text comments. This survey focused on the challenges, issues, and expected features from the perspectives of developers, teachers, and students, respectively. Our results revealed several challenges that developers face when building a metaverse, such as technical infrastructure, student engagement, avatar customization, and performance optimization. Meanwhile, teachers emphasized potential issues that may arise from the use of metaverse technology in educational settings, such as learning outcomes, health and safety, digital citizenship, and ethics and morality. Finally, students expected key features of the metaverse application, such as socialization and collaboration, virtual world interactions, metaverse optimization, realistic graphics, and minigames and activities.

The implications of these findings are significant as they can serve as a blueprint for metaverse technology adopters on how to build a virtual world tailored for educational experiences. Our findings can also help other educational institutions to develop their metaverse applications that align with academic standards and best practices. For example, uncovering the challenges associated with building a metaverse can inform future development efforts leading to a more efficient process. On the other hand, the issues raised by teachers can guide the formation of clear guidelines and protocols concerning metaverse use in education. Lastly, incorporating the metaverse features expected by students can help increase the adoption and utilization of the technology. From a theoretical standpoint, our study also strengthens the viability of a co-design approach and contributes to the existing empirical evidence on its effectiveness in educational technology research. Overall, the remodeling of the MILES Virtual World application offers valuable insights for educational institutions seeking to integrate metaverse technology into their academic services. In a time when technology is advancing at an unprecedented rate, it is more critical than ever to explore new and innovative ways of delivering educational experiences. Ultimately, the potential of the metaverse in education is significant, and our study provides a starting point for further exploration and development in this exciting and rapidly evolving technology and research field.

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