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# The Metaverse Design and Evaluation in Product Design and Development

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## ABSTRACT

The COVID-19 pandemic prompted a shift to online learning like SUT-Elearning, Zoom, and Google Classroom. However, these platforms have limitations in replicating classroom dynamics and fostering interaction. Students have low motivation for studying and class participation. The concept of a metaverse classroom is introduced, aiming to enhance engagement by exploring the Metaverse's origins, features, and educational benefits. This study delves into integrating metaverse technology into online education, using Suranaree University of Technology's product design and development course as a model. This course merges project-based and problem-based learning. The investigation outlines the gradual creation of a virtual classroom aligned with these traditional approaches, detailing its functions, components, and limitations. The classroom design is evaluated through student feedback gathered from interviews and surveys. Students assess the design's advantages and disadvantages and compare between the Metaverse, physical classes, Zoom, and video-based learning. Results drawn from feedback from 20 students highlight a preference for physical learning, closely followed by the Metaverse, which excels in engagement over Zoom and video. The Metaverse also excels in real-time interactions, with minor differences in self-directed learning. The study emphasizes the potential of integrating the Metaverse as a catalyst to improve online education and immersive learning. It highlights the ability of metaverse integration to increase real-time engagement and support innovative instructional methods. These methods are vital in effective online education, particularly in the ever-evolving educational landscape.

**Keywords**: Metaverse, Metaverse for education, Product design and development

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## 1. Introduction

Product design and development processes play a pivotal role in fostering innovation and driving economic growth across diverse industries. The efficacy of these processes hinges on the proficiency and knowledge imparted through design and development education, equipping students to tackle real-world challenges. Consequently, approaches rooted in project-based learning and problem-based learning assume significance as they propel students to engage in authentic, hands-on projects aligned with genuine conditions and requirements. These methodologies bolster students' aptitude for problem-solving, nurture their creative faculties, and cultivate a more profound comprehension of product development processes and designs.

However, the advent of the COVID-19 pandemic has necessitated a shift from traditional onsite learning to online modalities. Educators have had to devise novel methods and formulate new tools to support virtual education. Many online applications and platforms, including ZOOM, Google Meet, and Teams, have been developed and adopted. Suranaree University of Technology has also introduced an online learning platform called SUT-Elearning, which facilitates instructors in creating and managing virtual classes. This platform accommodates content dissemination, testing, information updates, and resource linking. Although many lectures were conducted via the ZOOM application, students faced challenges in joining sessions due to internet connectivity issues or health concerns. Consequently, alternative methods, such as recorded videos, were crafted to assist students who could not participate during scheduled sessions.

However, it became evident that several students lacked the motivation to engage fully in the online learning environment and preferred traditional classrooms (Tanaiutchawoot, 2022). This resulted in diminished class participation, leading to predominantly one-way communication. Students attributed this disinterest to the uninspiring nature of the online format. Students and instructors often deactivate their cameras; some felt apprehensive about actively participating or responding to questions. Nonetheless, some students favored online learning for its flexibility and convenience in terms of class switching without the need for physical travel. This allowed for timely attendance without disrupting their morning routines, offering the flexibility to learn from any location with internet connectivity. It showed that online learning does not affect students' ability to learn new knowledge, but they lack motivation and classroom participation (Tanaiutchawoot, 2023).

As described in the previous section, online learning has advantages and disadvantages. Consequently, there is an imperative to enhance online learning experiences by imbuing them with greater engagement. This entails creating an intriguing virtual classroom environment that instills a sense of immersion akin to that experienced within a physical classroom. The current era witnesses the prominence of metaverse technology, which provides an avenue to augment the sensation of active participation in authentic scenarios, even if physically absent. Consequently, this paper seeks to apply metaverse technology to online teaching and learning, enhancing engagement and fostering a more captivating atmosphere for virtual education. The primary goal is to engage learners more effectively. Within this study, a metaverse classroom was conceived and implemented within a product design and development course, serving as a case study to solicit student feedback on preferences and opinions.

## 2. State of the Art

### 2.1. Origin and Features of a Metaverse

The term Metaverse, which is a compound word with "meta" and "verse," was first introduced in 1992 in the cyberpunk science fiction novel Snow Crash (Stephenson, 2003). However, this concept was still unrealistic and required technologies. The Metaverse was proposed again in 2007 as a fusion of virtually enhanced physical reality and physical-persisted virtual space (Smart et al., 2007). A fusion of technologies for virtual and real education environments enhanced the education environment. Students can learn without being limited by time and location.

Moreover, they can use digital identities to have real-time interactions, such as avatars and virtual learning resources. Four scenarios were categorized in the metaverse roadmap under limited technology: augmented reality, lifelogging, virtual worlds, and mirror worlds. Many advanced technologies have been proposed in the online world where people can present themselves in headsets or glasses. The Metaverse is a collection of emergent technologies such as 5G, AI, VR, AR, digital twins, blockchain, and IoT (Kang, 2021),( Sparkes, 2021).

## 2.2. The Framework of the Metaverse in Education

The Metaverse was divided into three main components (hardware, software, and contents) and three approaches (user interaction, implementation, and application) (Park & Kim, 2022). It requires up-to-date technologies to enhance the quality of education environments in the Metaverse. Therefore, technology infrastructure is essential for Metaverse in education (Zhang et al., 2022). These technology infrastructures include communication and networks, computing technologies, analytical technologies, modeling rendering technologies, interaction technologies, and authentication technologies. These components can affect the quality of Metaverse in education. Metaverse was applied in many convergence subjects to improve effective communication by cooperating education in companies and Colleges such as LG, Seoul National University, and San Jose State University (Jeon, 2021).

A comparison of in-person learning, screen-based remote learning, and Metaverse-based learning were compared with different features: the time and location for learners to participate in class, learner identity, the people learners interact with, learning scene, learning resource, learning activity, learning interaction, learning objective, and learning assessment. From these features, the Metaverse seemed more beneficial in all aspects than other learning methods. Traditional education conducts specific teaching activities- in particular locations. Online courses were proposed after the internet became popular. However, it still relies on content delivery, classrooms, and textbooks (Friesen, 2017). Many problems were not resolved, such as the lack of engaging teaching content and the low willingness of student participation. Learning in the virtual environment, on the other hand, forms a new networked communication space (Paik et al., 2004). Students and teachers can have better communication supported by a whole management system. Virtual environment education can be divided into two types: the personal teaching environment (PTE) and the personal learning environment (PLE) (Yavich & Starichenko, 2017). The first type focuses on the teacher. The teacher can share specific knowledge on platforms; the visitors can then comment and download training materials. The learner builds and maintains the second type, including all components of educational programs, like terminals and communication. This type can be called lifelong learning, which is feasible for everyone (Noguchi et al., 2015).

Therefore, the Metaverse can change the interaction between students & teachers and new teaching actions. Hong Lin and his teams summarized the seven positive impacts of Metaverse: immersive interactive experience, visualization, low learning costs and risks, unrestricted time and space, preventing academic misconduct, personalization, and promoting communication (Lin et al., 2022). The study from Xiaoyang and Xiaoqing shows that Edu-Metaverse can enhance student learning outcomes by accelerating learning and skill acquisition (Shu and Gu, 2023). The Metaverse enables students to acquire knowledge across various subject domains from any location, bringing the concept of studying for practical application to fruition (Hwang et al., 2023).

## 2.3. Product Design and Development Education

The evolution of product design education can be traced back to the early 20th century when it was primarily focused on traditional disciplines like industrial design and engineering. Over the years, product design education has adapted to the changing needs of industries, incorporating multidisciplinary approaches to address complex problems. This evolution has led to the integration of user-centered design, sustainability, and design thinking concepts. These designs are integrated during product development; therefore, students should also be skilled in the methodologies and processes of product development for innovative products. In product development processes, a developer should understand the market and needs.

Then, he interprets these requirements to the product specification and design (Ulrich et al., 2008).

Marina Ricci and her team applied the Metaverse in a multidisciplinary laboratory in the industrial design program (Ricci et al., 2023). This focuses on the interaction between users and products to support how people communicate and interact in their daily and working lives. This lab helped students with the knowledge and tools needed to design new services for the Metaverse. The most critical aspect is the need to provide multidisciplinary and deeply integrated subjects such as computer science, computer-aided design, computer graphics, human cognition, user-centered design, human–computer interaction, and product design (Lundgren et al., 2006). However, industrial design students' feedback regarding acceptance, effectiveness, usefulness, efficiency, and satisfaction showed results that, although preliminary, were highly favorable and encouraging. Although the Metaverse in the product design and development class is rarely studied and explained, some researchers applied the Metaverse to analyzing customer behaviors to create a product idea and get customer feedback after the design (Kovacova et al., 2022), (Xu & Ye, 2023).

## 3. Concept and Limitations of Designing Metaverse for Product Design and Development Class

Based on information from the literature, the researcher aims to implement the concept of the Metaverse in the product design and development class. Accordingly, the metaverse class is structured using principles from traditional classroom settings while considering technological constraints and budget limitations.

### 3.1. Traditional Class

This course was meticulously devised and tailored to the learning environment at Suranaree University of Technology. The university's academic calendar comprises three semesters, necessitating the course's completion within 13 weeks, encompassing class evaluations. The framework for student learning was fashioned, drawing from the principles of Bloom's Taxonomy (Forehand, 2005). The pedagogical approach involves students receiving instruction from the primary lecturer and invited subject matter experts. These sessions serve to impart fundamental insights into the realm of product design and development. An external expert is engaged to elucidate the intricacies of Intellectual Property (IP), a salient topic essential to students' comprehension when delving into product design. In certain instances, group-based learning is employed, wherein students collaboratively address subjects such as product designs for diverse manufacturing processes. Subsequently, students present their findings to their peers, facilitating knowledge dissemination. These activities are designed with an active learning concept in mind.

A weekly workshop follows each lecture, allowing students to apply the content covered during the class. This dual learning approach allocates three hours for lecture content assimilation and another for practical application within the workshop. Consequently, students engage in hands-on exercises to refine their skills, enabling them to grasp the utility and nuances of the methods and techniques elucidated in the lectures.

Upon absorbing the comprehensive knowledge imparted, students are evaluated through an examination designed to gauge their foundational understanding before embarking on the final project. Organized into groups, students commence their projects, entailing the conception and development of new products. The focal themes of these culminating projects vary, adapting to the specific context of each academic year. The topics might be derived from existing corporate challenges, designing new products for their respective hypothetical companies, or creating novel solutions for an identical application. To achieve these outcomes, students amalgamate insights garnered both within and outside the classroom, employing their collaborative efforts to craft prototypes for the ultimate project. Their efforts culminate with a presentation outlining the new product's design and development trajectory. The final presentation encompasses a one-minute advertisement video, a prototype rendition or product, and a PowerPoint presentation. The overall class design is presented in Figure 1.

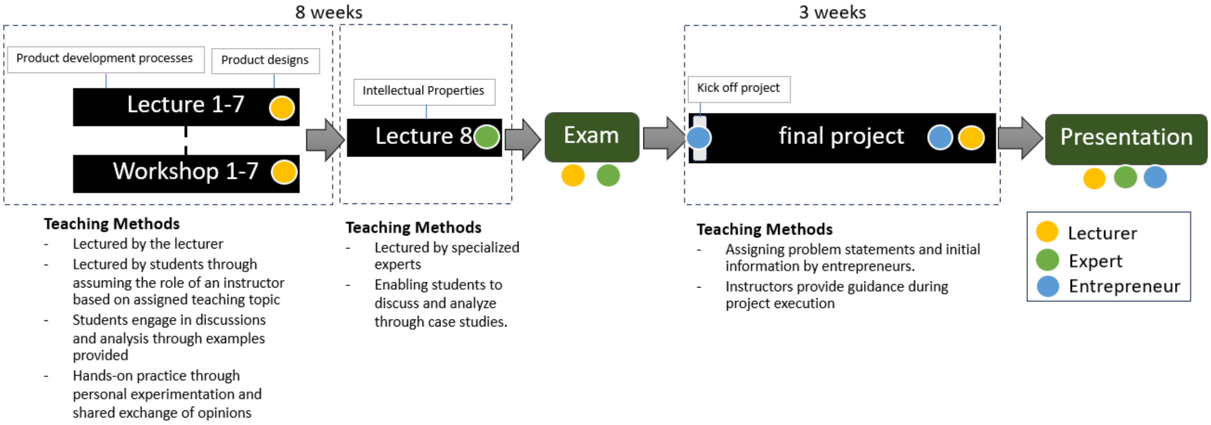


*Figure 1.* The overall class design for product design and development

However, considering the COVID-19 pandemic, the dynamics of this course transformed, necessitating the transition from traditional onsite classrooms to a virtual online format. The lecturer leveraged the SUT learning application for classroom management, while the ZOOM and Miro applications facilitated real-time classes and workshops. The latter, Miro, proved conducive to promoting creative exercises like brainstorming, persona creation, and scheduling planning. Despite the altered format, students continued to undergo assessments and work on their final projects. However, the tangible prototypes were limited to digital manifestations, such as CAD files and 3D models, due to the constraints imposed by the virtual setting.

### 3.2. Classroom Modification for Metaverse Design

Derived from the conventional classroom framework, the Metaverse is expected to accommodate two primary activities: lectures and workshops. Ideally, Students should receive instruction from lecturers and engage in collaborative group tasks. Additionally, they can reinforce their learning by reviewing recorded videos. Consequently, each lecturer should have a dedicated space to centralize all materials for their respective lectures. Similarly, students should be allowed to conduct workshops and finalize their projects. Furthermore, this room could also serve as a meeting space for student discussions. This metaverse classroom, therefore, has the potential to replace the SUT e-learning platform, ZOOM application, and Miro application. Another purpose of the metaverse classroom is to function as an exhibition venue for students and interested entrepreneurs or business owners. The exhibition hall showcases student works from the final projects, featuring 1-minute video presentations and 3D models. The conceptual design of the metaverse classroom for product design and development is illustrated in Figure 2.

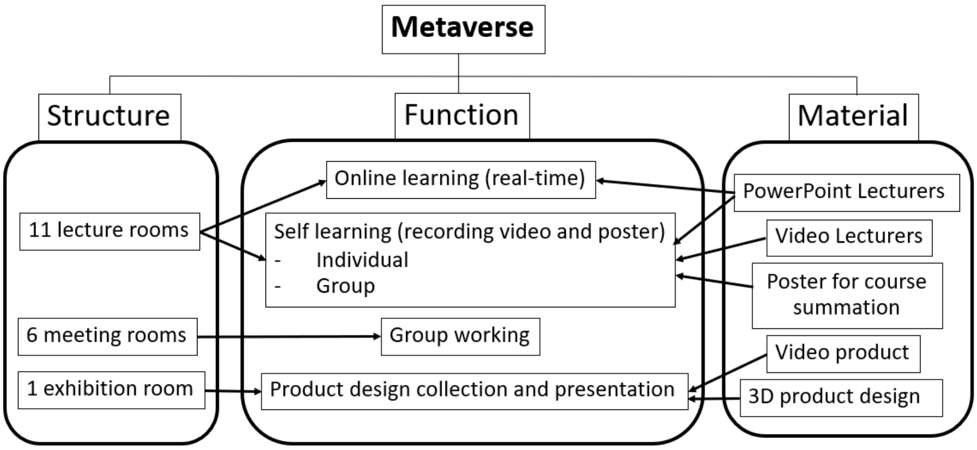


*Figure 2.* The concept design for the metaverse classroom

The metaverse classroom was constructed using the Spatial application, freely available for crafting 3D workspaces to foster collaborative cultural experiences. Nevertheless, this software presents certain limitations, rendering it inadequate to fulfill all the requirements set forth by the lecturers. Notably, the platform cannot record user data, thus precluding the implementation of examination functions within the classroom. Furthermore, this program only offers the role classifications of user and developer. The user roles cannot be finely categorized to specify aspects such as room access privileges, screen sharing permissions, and similar details. Regarding limitations in budget, spaces, and personal characters, this classroom does not include technologies such as 3D glasses, haptics, and sensors. This class requires only display devices with an internet connection, such as computers, laptops, tablets, and mobile phones.

## 4. The Result of the Metaverse in the Product Design and Development Class

Upon entering the metaverse classroom, the central room is conceived as the initial space. Students will access information about the lecturer's background and course syllabus here. The lecturer can provide a course introduction within this room. Subsequently, students can proceed to the lecture rooms as the class commences. In each room, the lecturer tailors the metaverse environment distinctively, aiming to heighten students' motivation to explore all available spaces. Lecture materials and videos can be downloaded by students through links provided in each room. The illustrations of the central room and lecture rooms can be found in Figure 3.

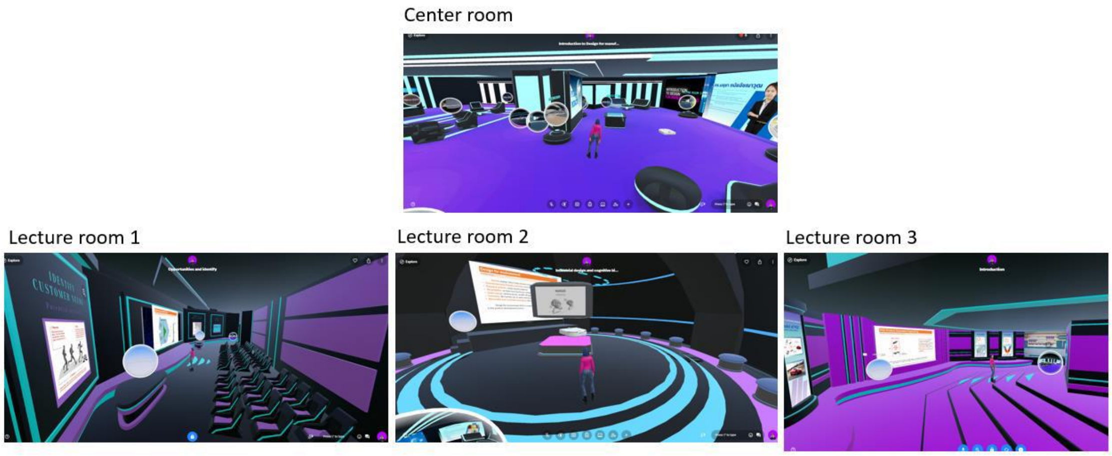


*Figure 3.* Examples of the central room and lecture rooms

The meeting rooms, as depicted in Figure 4, are purposefully designed with clear distinctions to avert any confusion upon entry and to ensure seamless observation of the lecturer's interactions. Within these rooms, students can introduce items and share their screens to engage in discussions with their peers. This renders the meeting room an accessible option for all students, especially those situated in diverse locations, aiming to collect data collaboratively. For group activities like brainstorming and design thinking, the room provides a convenient space for members to store all relevant materials. This setup simplifies the process of accessing and modifying ideas within the room. This room also benefits the lecturer in evaluating students' progress and supporting students when they go in the wrong direction in their assignments.

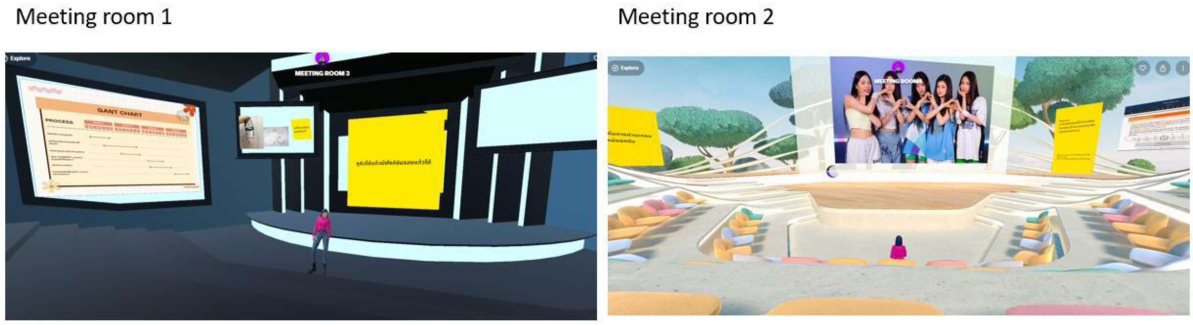


*Figure 4.* Examples of meeting rooms

The appeal of the metaverse classroom is enhanced by features within the Spatial application, such as the ability to generate avatar users from their images, avatar body movement, emojis, screen sharing, video recording, and box chat (as depicted in Figure 5). There are instances when students or even the lecturer might choose not to activate their cameras during lessons, potentially resulting in a diminished ability to recall the faces of both students and instructors. Creating avatars is an alternative solution, mitigating this concern and fostering a sense of direct interaction between students and the instructor. Concurrently, lecturers also experience a heightened sense of engagement, feeling like they are interacting with students more personally rather than merely addressing a computer screen. An example of a real-time metaverse classroom is illustrated in Figure 5.


*Figure 5.* Examples of meeting rooms

## 5. Comments and Feedback from Students and the Lecturer

The assessment of the metaverse classroom's effectiveness involves two primary components. Initially, this approach is compared to three other methods: the traditional onsite classroom, the online classroom using ZOOM, and the online classroom employing video recording. A cohort of twenty students enrolled in the 2023 product design and development course participated in classes with diverse teaching methodologies each week. Traditional classroom sessions occurred during the 1st and 4th weeks. The online class utilized ZOOM and video recording during the 2nd and 5th weeks and the 3rd and 6th weeks, respectively. The Metaverse was employed for the remaining classes. Students subsequently rated their satisfaction at the end of the course with the learning formats by assigning preferences on a scale of 4, 3, 2, and 1 for the first (highest preference), second, third, and fourth (lowest preference), respectively. The outcomes, indicating the average scores from the 20 students who enrolled in the class, are depicted in Figure 6. These results are subjected to statistical analysis using the Mann-Whitney U Test to ascertain differences between each teaching method, with a significance level set at 0.05. The detailed findings are presented in Table 1.

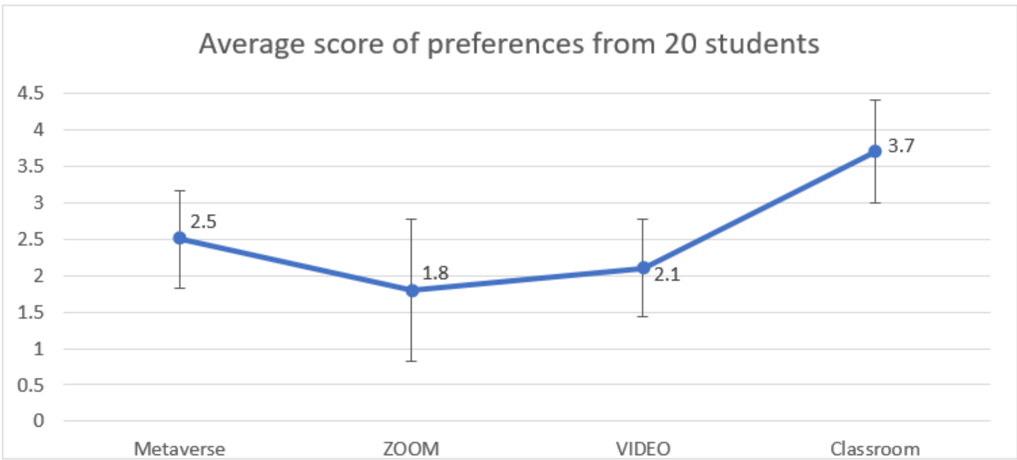


*Figure 6.* The average scores of student preferences for different learning methods, including Metaverse, ZOOM, video, and traditional classroom

Table 1.
*The analysis involved utilizing the Mann-Whitney U Test with a p-value of 0.05 to assess the results of student preferences for each learning material*

| Z score | Classroom | ZOOM | Metaverse | Video |
|---|---|---|---|---|
| Classroom | - | Z=4.31, $p<0.05$ | Z=4.40, $p<0.05$ | Z=3.94, $p<0.05$ |
| ZOOM | - | - | Z=-2.48, $p<0.05$ | **Z=-0.91, p>0.05** |
| Metaverse | - | - | - | **Z=1.50, p>0.05** |
| Video | - | - | - | - |

The outcomes derived from Figure 6 and Table 1 indicate that most students prefer traditional classroom or onsite learning in contrast to various online learning methods. The preference for learning in the conventional classroom is notably distinct from the other methods. Upon comparing online learning approaches, it becomes evident that students favor metaverse-based learning over learning via recorded videos and ZOOM. Among the online learning methods, the ZOOM application is the least preferred among students. However, from a statistical perspective, there is no significant variance in preferences between learning via ZOOM, recorded videos, or the Metaverse.

Nonetheless, a noticeable preference disparity exists between metaverse-based learning and ZOOM. These findings imply that students still prefer in-person learning within a physical classroom. However, the Metaverse is a favorable choice for real-time learning when transitioning to the online classroom, surpassing ZOOM. Conversely, students do not perceive a significant differentiation between learning through the Metaverse or recorded videos in self-guided online learning. Both students and the lecturer (researcher, expert, and entrepreneur) commented on their experience in the metaverse class, highlighting both advantages and disadvantages. These aspects have been summarized in Table 2.

Table 2.

*The analysis involved utilizing the Mann-Whitney U Test with a p-value of 0.05 to assess the results of student preferences for each learning material*

| Participants | Advantages | Disadvantages |
|---|---|---|
| The lecturer | • It allows students to express their opinions more easily.<br>• It enables the perception of engagement during lessons through student movements, such as walking back and forth, dancing, and sending emojis.<br>• It allows an expert and entrepreneurs to participate in class without traveling. | • Unable to write, limiting additional explanations or assigning group tasks<br>• Screen clarity is compromised, needing to choose between looking at the screen or students<br>• Audio is not audible when playing videos through screen sharing<br>• Videos restart if there's a room change<br>• Some videos can't be opened<br>• If a long video is recorded, it might be challenging to locate the saved file. |
| Student | • Communication becomes more accessible through gestures and emotions<br>• It's like playing a game<br>• Can learn and work from anywhere | • Requires a high-speed internet connection to prevent disconnections, lagging, and occasional loss of audio.<br>• Screen visibility is blurred at times due to obstructing classmates<br>• There are limitations in conducting workshops for creating mechanical prototypes |

## 6. Discussion and Conclusion

Based on the results of the experiments, students' perspectives towards different learning and teaching materials in the product design and development class become evident. Despite attempts to emulate classroom settings, it is observable that students exhibit a stronger inclination towards onsite classroom learning, even though efforts are made to recreate classroom-like environments. This discrepancy arises due to the absence of a lifelike sensation, which the lecturer may need to enhance by incorporating devices that stimulate a more realistic experience, such as an augmented reality glass and a haptic device. This result confirms the knowledge from the literature that supporting technologies are necessary to encourage metaverse effectiveness in education. In this context, some students express that classroom-based learning seems more controlled by the lecturer than online learning, necessitating a higher level of attentiveness in the classroom. Anyway, these devices are expensive and require space for installation, which is inconvenient for some students. Furthermore, the learning environment varies among individuals during online learning. While some students study in private areas, others engage in virtual classrooms within commercial establishments or cope with low internet connectivity in specific locations. Therefore, in-class learning entails harmonizing students' environments to a uniform state.

Conversely, within online education, the impact of the learning experience is more pronounced when the lecturer delivers real-time lectures. Creating a classroom-like environment in real-time stimulates learning more effectively than learning through video-based environments. This phenomenon is evident in multimedia systems with features that augment background visuals and embellish participants' appearances, enhancing engagement in discussions. However, in cases where learning focuses on self-directed exploration, the instructional modality appears to have limited influence on the learning outcome, as learners' predispositions towards self-directed learning prevail from the outset. Consequently, learners prioritize convenient study times and content comprehension over environmental factors.

Consequently, the disparity in learning outcomes between video-based and alternative instructional methods is minimal. However, these premises are preliminary hypotheses derived from the researcher's findings. Thus, further experimentation is imperative, involving a larger participant pool, increased experimental iterations, in-depth interviews, and expanded investigations into additional subjects. Nevertheless, the researcher remains confident in the enduring significance of online education as a valuable and contemporary pedagogical alternative. Utilizing metaverse-based instructional approaches invigorates the learning experience for both students and instructors, aiming to create an immersive atmosphere. This information underscores the significance of integrating various devices and technologies to enhance the authenticity of the metaverse learning environment. In doing so, the acceptance of metaverse-based education is poised to increase substantially.

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