Investigating Student Learning in Metaverse

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Abstract*—This full research paper describes a comprehensive study on student learning within the metaverse. A trend has emerged in response to recent shifts in learning habits, which results in the need for adaptable remote learning solutions. Instead of using typical virtual conference tools, class communication can be boosted by utilizing the metaverse - a trendy platform transient from the traditional virtual world, letting users interact with their environment via a Virtual Reality (VR) device. Unlike its predecessors, the metaverse transcends the confines of the traditional virtual world, offering users immersive interactions facilitated by Virtual Reality (VR) devices. However, a notable gap exists in research regarding user interactions via VR devices. This study attempts to address this gap by exploring how the non-coding features inherent in existing metaverse platforms can be harnessed to enhance students' learning experiences. Through analysis and experiment, this research provides valuable insights and recommendations to aid future instructors in effectively integrating metaverse-based activities into their teaching methods. Our overarching objective in the study is to explore how the metaverse can amplify student learning performance and foster deeper engagement. Initially, a complete taxonomy of classroom activities is developed to evaluate the suitability of multiple existing metaverse platforms for educational purposes. Following this evaluation, Spatial.IO appears as the platform for hosting the course components for our investigation into student learning. Programming features are intentionally forbidden when creating learning materials to simulate the experience of an average user in developing classroom activities. Consequently, a collection of class components is fashioned in documents (e.g., posters) and video forms, measuring the effectiveness and potential drawbacks of utilizing the metaverse for educational purposes. Comparative analysis between learning experiences in the metaverse and traditional browser-based settings reveals fascinating insights. Students exhibited promoted focus within the metaverse environment. Document reading within the Metaverse via VR proves more effective than conventional browser-based platforms. Nevertheless, video-based learning experiences in the metaverse are found to be less effective than their browser counterparts. These findings can serve as invaluable references for future instructors who seek to leverage the metaverse as a tool for education.

Keywords*—*Metaverse, Virtual Reality, Learning Technology, Distance learning

I. INTRODUCTION

The metaverse is an emerging platform that has attracted significant attention from many information technology (IT) companies. The global market of the metaverse is estimated to reach 758.6 billion US dollars by the year 2026 [1]. Due to COVID-19, the digitization of our lives accelerated. Schools recognize the new habits derived from using online communication software like the remote meeting tool in the classroom. This new normal learning style, which engages more persistent and multi-purpose online communication, drives us to explore more potential in teaching and learning. Thus, after the pandemic, this trend made us rethink "virtual learning," looking for a new definition of gathering virtually.

Due to advances in IT technologies, the virtual environment can also make it feasible to quickly go beyond time and space, which differs from traditional face-to-face learning. Many technologists believe the metaverse offers complementary activities between traditional face-to-face learning and e-learning. Compared with remote conference styles, the metaverse should enhance perceptions of the environment and other people's existences. As a result, we increased our interest in exploring new teaching and learning approaches in the metaverse.

However, the virtual world is not a new concept. The traditional virtual world built upon Web 2.0 technologies lets users enter a virtual space to create 3D objects through a web interface. Second Life is a well-known Web 2.0 example. It is widely applied in various domains [2]. However, metaverses integrate many of the latest technologies, such as virtual reality (VR) headsets and mobile networks, to deliver more functionalities and interoperability. The metaverse envisions the future internet as a more immersive user experience because VR devices have improved the user experience by dropping current mouse-clicking operations. Through a VR headset, new operations, such as eyeball tracking, audio, or gestures, could be the interactions among humans or between humans and objects in the metaverse.

Previous studies [3-10] mainly performed research in various courses to explore novel learning approaches, gain useful facts from observations, or discuss their advantages and disadvantages in the traditional virtual world. From past research, we can infer that the metaverse owns similar benefits and drawbacks as the traditional virtual world due to the 3D presentation and avatar; the new means (e.g., VR device) and its corresponding interactions in the metaverse bring a different influence to education (see Table 1). This new influence comes with unknowns, indicating a need for student learning research in the metaverse. Unlike previous studies on 3D virtual world browsing and mouse or keyboard operations, we need to explore more applications that interact with new interfaces inside the metaverse through a VR headset and examine their impacts. However, creating these applications becomes more complicated because many metaverse platforms are maintained for the marketplace. The first challenge is that educators need help understanding the choice of technologies. Even though they can select a workable metaverse, they might not thoroughly understand its limitations and how it will influence student learning.

As a result, this paper aims to understand students' performance and perceptions about learning in a metaverse. We start by evaluating many existing metaverses to select one suitable for various classroom activities. Once selected, a set of class components will be created without the need for programming to conduct experiments. Experiments for two groups are executed to investigate student learning. Finally, we discuss our findings and present insights into students' metaverse learning activities.

TABLE I. COMPARISON BETWEEN TRADITIONAL VIRTUAL WORLD AND METAVERSE

	Web 2.0 Virtual World	***Web 3.0 Metaverse***
Content Creators	Game studios and/or developers	Community Game studios and/or developers
Digital Assets Portability	Locked within platform	Transferable
Platform	PC (web) or Mobile (app)	PC, mobile, Virtual Reality (VR) or Augmented Reality (AR) hardware
Interaction	Audio or mouse clicking	Eyeball tracking, audio, or gestures
Example	Second Life	Decentraland, Roblox, Sandbox, and etc.

II. LITERATURE REVIEW

The usage of the metaverse in education has recently increased due to its potential to transform traditional teaching platforms into a more interactive and effective environment. While the virtual environment helps students gather from everywhere, its immersive and interactive experience can drastically impact learning. For instance, students can sit at one table from different continents and check various properties of the resources in 3D space. Moreover, virtual reality can be utilized to manipulate 3D objects as it becomes a standard commodity hardware available for the average user [11].

Among the papers investigating the use of metaverse in various fields, several studies utilize virtual reality and computer simulations to provide training and address safety. For instance, Chittaro et al. [12] aim to educate passengers about aviation safety through playing immersive games. The method is compared with a traditional one called safety card, and experiments imply that an immersive game can produce more engagement and less negative emotion or fear. Similarly, immersive virtual reality simulators can assist workers in preventing accidents by detecting behavioral patterns that may lead to risk exposure [13].

Since the metaverse can readily assist with safety issues, it can provide a hands-on approach for students. For example, Kanematsu et al. [14] proposed a blended method that included lectures and metaverses with hands-on activities in nuclear safety. Students could easily measure radioactivity in different situations within the virtual classroom, and the final survey results show the effectiveness of the proposed blended method in STEM education.

Since problem-based learning (PBL) is very useful in real classrooms, some educators wondered if it would be effective in the virtual world. Barry et al. [15] proposed an approach in which a team of students worked on a problem by brainstorming in the virtual classroom and building a home for the near future during global warming. Due to the method's virtual characteristics, American and Japanese students participated in the study, and it was cost-efficient since they did not need to buy real materials.

Computer vision is a field of artificial intelligence that can cooperate with metaverse systems due to its automated interpretation of visual information. Object detection and recognition through visual scenes is a widespread technique in computer vision that can assist with providing avatars that mimic student faces. Students can have an avatar with eye blinking capability that can be analyzed during problem-based learning assignments. Barry et al. [16] investigated whether the number of student eye blinks increased with the difficulty of the problems. For instance, Haar-cascade [17] can be utilized for face and eye detection. If the face is detected and the eye is not detected, this indicates the eye blink. This information is communicated to the avatar.

Although utilizing the virtual world and hybrid education is beneficial for student learning, there are some limitations to the educational applications of the metaverse. Kye et al. [18] defined four types of metaverse, with applications and use cases called augmented reality, lifelogging, mirror world, and virtual reality. While augmented reality overlays digital information such as images and text in the real world through digital devices (e.g., smartphones, glasses), lifelogging is more about collecting and capturing personal experience within the metaverse. For instance, Shapavalov et al. [19] investigated utilizing personal smart tools such as smartwatches in STEM education. They showed that they can assist with developing student thinking through graphs and calculations and involve students in individual research. On the other hand, the mirror world plays a key role in resembling real classrooms inside the virtual world, reducing the gap between the physical and digital realms and making students' experiences comfortable and efficient.

III. APPROACH

Initially, we gathered data on all existing metaverses and assessed them to identify the most suitable option for our experiments. Subsequently, we developed a range of course components and integrated them into our designed experiments. Finally, we proceeded to analyze the outcomes derived from these experiments.

Secondly, we reviewed several theoretical frameworks focused on the metaverse and their application in education. We considered using the Cognitive Theory of Multimedia Learning (CTML), developed by Richard E. Mayer [23]. It offered valuable insights into how learners process information from different modalities, particularly visual and auditory channels. CTML emphasizes the importance of presenting information in ways that align with our cognitive architecture, reducing cognitive overload, and promoting active processing. Fundamental principles of CTML, such as the multimedia principle, contiguity principle, and modality principle, can guide the development of engaging and compelling multimedia content within the metaverse.

However, the User Experience (UX) Theory [24] better fits our research questions. Therefore, we adopted the User Experience (UX) Theory to explore the effectiveness and usability of educational technologies, explicitly focusing on Virtual Reality (VR) and browser-based platforms. UX Theory provides a comprehensive framework for analyzing user interactions, encompassing critical dimensions such as usability, engagement, aesthetic appeal, and overall satisfaction. By applying UX Theory, we aim to assess whether VR's immersive and interactive features offer an enhanced learning experience compared to traditional browser-based methods. Inspired by how the UX factors "desirability," "perceived usefulness," and "motivation to attend" are measured in previous studies (see Table 2), we would analyze students' responses to identify descriptions related to the factors we want to assess. This theoretical lens enabled us to evaluate how these platforms support or hinder learning, considering factors like ease of use, cognitive load, and emotional responses, which are crucial for determining student satisfaction and learning outcomes.

TABLE II. UX MEASUREMENT FACTORS AND STATEMENTS [24]

Factors	***Sample of Statement***
Positive desirability (enjoyment)	“I feel good.” “I enjoy it.” “I feel happy.”
Perceived usefulness	“The quiz helps me to understand the subject.”
Motivation to attend	“I get excited about joining.” “I am motivated to join.”

A. Metaverse Exploration

We investigated existing platforms in two steps. In the first step, we wanted to know a metaverse’s adaptability, device support, avatar and world styles, and controllability. Metaverses used in classroom activities would be selected as candidates for in-depth investigation. After selected candidates were further investigated according to the various types of classroom activities, the one used for this research case study would be determined.

The platforms we investigated included Roblox, Sandbox, Bloktopia, Discentraland, Metahero, Illuvium, Star Atlas, Cryptovoxels, AltspaceVR (Sunsetting), Microsoft Mesh, Meta Horizon Workrooms, and Spatial.IO [20]. These metaverses were collected according to claims from many online news outlets, blogs, and online forums.

Many so-called metaverse sites are not virtual spaces. They are platforms or tools that support metaverses. These include Bloktopia and Metahero. The others are gaming tools; IIlluvium and Star Atlas belong to this category. Another category is about those that cannot support VR devices or sunsetting. Microsoft Mesh, AltspaceVR, and Roblox belong to this kind. As a result, our in-depth investigation will be done in Discentaland, Cryptovoxels, Spatial.IO, and The Sandbox.

TABLE III. METAVERSE INVESTIGATION TEMPLATE

Attributes	***Metaverse Name***
Adaptability and Buildability	At what level does the metaverse support room and 3D object building, and avatar creation?
Device Support	What device can the metaverse support? Website, VR device (e.g., Oculus, Oculus2), and Mobile.
Avatar Appearance Styles	Lego block, cartoon, or realistic human style.
World Styles	Lego block or physical world style.
Controllability	Graphical user interfaces. How the metaverse support moving, creation, manipulation, etc.?
Cost	Cost for features for building a course component and classroom.

When choosing a metaverse. one important factor for us is style. Inspired by Bombari et al.’s study [22], which suggested realistic styles for better immersion, we chose realistic world and virtual human styles instead of block or cartoon styles for our research. Table 3 shows our investigation template on Discentraland, Cryptovoxels, Spatial.IO, and The Sandbox. All four metaverses have editing and viewing modes. Discentraland, The Sandbox, and Spatial.IO allow users to edit and view via browser and VR device. None of the metaverses can support object-grabbing operations without programming. Only Spatial.IO officially supports Oculus2. Ultimately, we choose Spatial.IO over the other three because its free tier supports features without programming, styles are like actual human worlds, and it provides many room examples for modifications.

- Uploading 3D models, documents, and image files
- Streaming
- Messaging
- Drawing a plate
- Creating 3D objects via scanning
- Playing videos

TABLE IV. FEATURES AND LIMITS OF METAVERSE [21]

	Spatial.IO
Computation	Not support
Lecturing/ Watching	Support by streaming or video playing
Reading	Support by uploading PDF document or image
Discussion	Support by the messaging feature
Exploration	Support. Need to design 3D objects or rooms for exploration.
Operation (Grabbing or Carrying Objects)	Not support unless writing scripts

B. Evaluating Metaverses for Classroom Activities

According to previous studies [21, 22], we listed the types of classroom activities as the criteria to evaluate existing metaverse platforms.

Types of Classroom Activities

- Computation (Hands-on)

- Lecturing (Watch and Listen)
- Discussion (Speak, Watch, and Listen)
- Reading
- Exploration and discovery (Observation)
- Operation (Hands-on)
    - In sequence (order) or not in order (Assembly)
    - Object creation and manipulation (Creation)

After we evaluated all the candidates, we selected Spatial.IO as the platform for hosting our class components. Table 4 shows how Spatial.IO supports each type of activity without any coding. Considering not writing a script to extend the metaverse was critical to our study. Because most users do not customize their metaverse spaces or avatars, our study can reflect the typical use cases for instructors.

IV. Research

A. Research Questions

We aim to investigate whether immersive effects can enhance students' learning performance and evaluate the impacts of different activities on student learning. Also, we seek to identify key considerations for developers or instructors when creating course materials in a metaverse classroom. Below, we outline our research questions.

1) RQ1: How does the metaverse enhance students' learning experience?

2) RQ2: How does the metaverse enhance students' learning performance?

3) RQ3: What are the affordances and signifiers in the design of learning activities in the metaverse?

We designed experiments to study the first two research questions. Because we developed course components for the experiments, the third research question can be investigated based on the course development experiences.

B. Metaverse Experiment Design

Before the experiment, all the participants needed to watch a video about using an Oculus2 to enter the metaverse classroom in Spatial.IO. They also learned how to use Oculus 2 before they started their experiments. Because we wanted to know that the student's knowledge was not from past learning activities, all students completed a pre-experiment questionnaire about the subjects that will be taught in the metaverse classroom.

TABLE V. Research Groups and Experiments

Teaching Material	***Group 1***	***Group 2***
Document 1: Introduction to Design Pattern Part1	Browser (control)	Metaverse (experiment)
Document 2: Introduction to Design Pattern Part2	Metaverse (experiment)	Browser (control)
Video 1: Singleton Pattern Part1	Browser (control)	Metaverse (experiment)
Video 2: Singleton Pattern Part2	Metaverse (experiment)	Browser (control)

Students were randomly assigned to two groups. Each group learned the same subjects from different means (i.e., browser and metaverse) at the same stage. Table 5 shows the research groups and the experiments at four different stages.

The platform's default functionalities governed the course components; no programming was required. We wanted to investigate how a metaverse can support course component development without writing code. The need for no coding provides a low floor for instructors to create their own classroom and course components. Through course component development, we can also understand how much effort and expertise an instructor needs to create a course component. Note that Documents 1 and 2 teach different points on the same topic, and Videos 1 and 2 do the same. The expected learning time for both videos and documents is designed to be around 5 minutes. Therefore, the overall learning process should take about 20 minutes. We intentionally made each learning component around five minutes to control for fatigue and attention and gain students' instant feedback and performance.

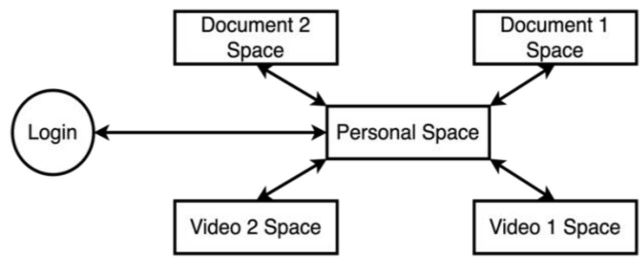

Fig. 1. Connections between metaverse classrooms

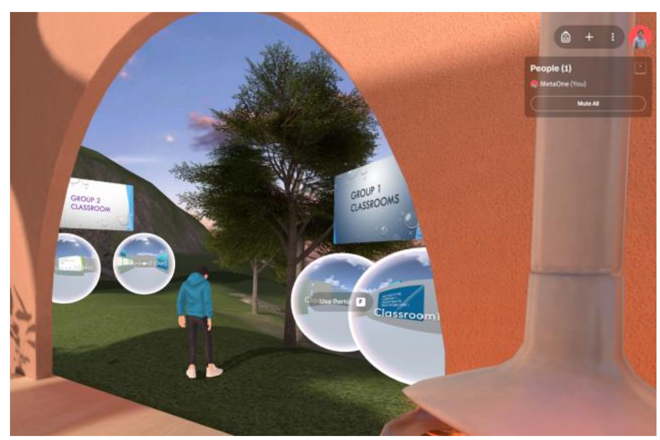

Fig. 2. Metaverse classroom entries

There are two ways to design the classroom. One is to make a room like a galley, which includes various learning materials distributed around the space. It is easier for course material developers to put everything together; learners only need to enter one room to access all the topics. However, course materials could interfere with each other when the user does not correctly handle them. It is also possible that learners with different learning targets will be put in the same room. The other way is to create multiple spaces that link to each other, and every space contains a specific topic the instructor wants to cover. Learners need to travel between spaces for learning. We decided to use the second approach to specify rooms for the experiment and control groups without possible interference.

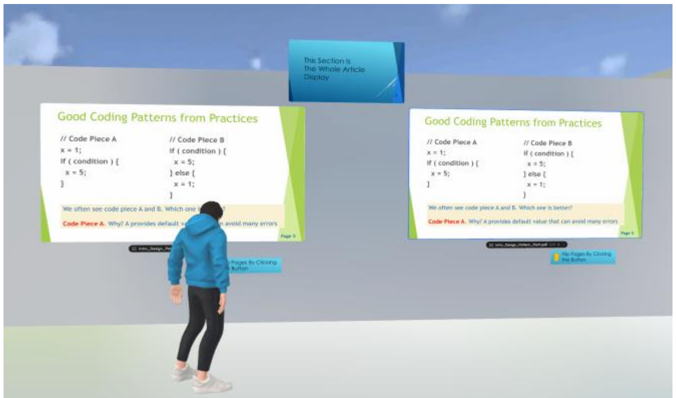

Fig. 3. Documents for Learning in a Metaverse Classroom

To note that, all users in Spatial.IO have their personal space as an entry point. This personal room cannot be customized for a classroom but can link to a space that the user creates. In our design, we make four spaces for different groups of students to learn a subject. Fig. 1 shows links between spaces, and Fig. 2 displays the teleport points to other rooms from the main entry point (i.e., the personal space in Spatial.IO). One space for learning through reading a document is shown in Fig. 3.

TABLE VI. QUESTIONS ABOUT STUDENT'S PERCEPTIONS ON LEARNING IN METAVERSE

Group	*NO.*	*Question*
F	Q17	Your overall feedback and feeling about learning from watching a lecture video in the metaverse? Please be specific.
F	Q18	"Which display format do you like better? (1) Moving avatar and then reading each page of an article (2) An article with next and previous buttons for reading each page"
F	Q19	Your overall feedback and feeling about learning from reading an article in the metaverse? Please be specific.
F	Q20	What pros and cons do you think about learning or viewing in the metaverse?

C. Survey

The post-experiment survey comprises two main sections: (1) knowledge tests covering the topics students encountered during the experiments and (2) students' perceptions of learning in metaverses. Questions 1 to 8 constitute the knowledge test segment, where the answers are directly drawn from the materials. These questions desire to assess the effectiveness of students' learning experiences with the materials. Questions in groups V and D allow us to gather students' perceptions regarding controls' enjoyment, effectiveness, and usability when watching videos and reading documents in the metaverse. Questions in group F (see Table 6) enable us to gather students' overall feedback on their learning experiences.

V. RESULTS

26 undergraduate students participated in this study, with Group 1 comprising 12 students and Group 2 comprising 14 students. The majority of students study Computer Science and Software Engineering. We interpreted results from a descriptive analysis of survey mean scores and did not employ statistical methods. We were primarily interested in user preferences, perceptions, and satisfaction. Iterations of this study will employ more sophisticated analysis to determine the significance of the results.

TABLE VII. FAMILIARITY OF TEACHING TOPICS BEFORE EXPERIMENTS

Topic	***Group 1***	***Group 2***
Threads (0 - 4)	2.417	2.786
Synchronization (0 - 4)	1.75	1.643
Java Programming Language(0 - 4)	1.582	1.429
Design Pattern (0 - 4)	0.75	1.071
0: I have not learned it before or know nothing ***1: I heard or learned this but only knows a little bit*** ***2: I learned this before and have basic understanding*** ***3: I am familiar with the concept*** ***4: I am an expert about it or know it very well***		

A. Quantitative Analysis

Table 7 reveals that the topic students are most familiar with is "threads", but the average values in both groups suggest they are only limitedly familiar with it. Students' responses indicate minimal prior exposure to that knowledge for all other topics, as all values fall below 2. Consequently, if students engage with these topics in the metaverse classroom, their learning experiences should be independent of their pre-existing understanding of the subjects.

TABLE VIII. TWO GROUP'S CORRECT ANSWER RATES

	Average Correct Answer Rate			
	Group 1	*Percentage*	*Group 2*	*Percentage*
Document1	Browser (control)	62.5	Metaverse (experiment)	64.286
Document2	Metaverse (experiment)	50	Browser (control)	28.571
Video1	Browser (control)	54.167	Metaverse (experiment)	50
Video2	Metaverse (experiment)	58.333	Browser (control)	64.286

In Table 8, students who read documents in the metaverse perform better than reading them in their browser because both groups correctly answer more questions after they learn in the metaverse. Watching a video has the opposite result. Students who watch a video in the metaverse perform worse than those who watch it on the browser. Both groups show the same trend in the comparison.

TABLE IX. RESULTS ABOUT CONTROLLABILITY, LIKENESS, FOCUS, BENEFITS ON DOCUMENT AND VIDEO LEARNING MATERIALS

Group-NO.	***Question***	***Group 1 (N= 12)***	***Group 2 (N= 14)***	***Avg.***
V-Q9	Do you think it is easy to pause, stop, or play video when watching a video in the metaverse? *0: very difficult 1: difficult 2: normal 3: easy 4: very easy*	2.083	1.714	1.899

Group-NO.	Question	Group 1 (N= 12)	Group 2 (N= 14)	Avg.
V-Q10	Do you like to learn by watching a video in the metaverse? *0: not like it at all 1: not like it 2: neutral 3: like it 4: like it very much*	2.167	2.143	2.155
V-Q11	Do you think watching a video in the metaverse environment makes you more focused than watching a video elsewhere (not in metaverse)? *0: not at all 1: somewhat less focused 2: normal 3: more focused 4: very much more focused*	2.583	1.786	2.184
V-Q12	Do you think watching a video in the metaverse is more beneficial to you than watching a video elsewhere? *0: not at all 1: somewhat beneficial 2: normal 3: beneficial 4: very beneficial*	2.083	1.929	2.006
	Average	2.229	1.893	
D-Q13	Do you think it is easy to move to next and previous pages when reading an article in the metaverse? *0: very difficult 1: difficult 2: normal 3: easy 4: very easy*	2.364	2.14	2.253
D-Q14	Do you like to learn by reading an article in the metaverse? *0: not like it at all 1: not like it 2: neutral 3: like it 4: like it very much*	2.455	2.286	2.370
D-Q15	Do you think reading an article in the metaverse environment makes you more focused than reading an article elsewhere (not in metaverse)? *0: not at all 1: somewhat less focused 2: normal 3: more focused 4: very much more focused*	2.366	2.5	2.432
D-Q16	Do you think reading an article in the metaverse is more beneficial to you than reading an article elsewhere? *0: not at all 1: somewhat beneficial 2: normal 3: beneficial 4: very beneficial*	1.455	1.929	1.691
	Average	2.159	2.214	

In Table 9, Group 1 demonstrates values above 2 in V-Q9, V-Q11, and V-Q12 for watching a video in the metaverse, whereas Group 2 presents values below 2. These inconsistent results reflect varying perceptions regarding video playback control, level of focus during viewing, and the learning effectiveness through video watching. However, both groups agree that they prefer learning by watching a video in the metaverse. Concerning reading documents in the metaverse, both groups share similar perspectives, finding document control manageable and experiencing strengthened focus. However, they disagree that reading an article is effective in the metaverse and are reluctant to learn this way. Furthermore, students exhibit no preference differences between the two document exploration methods (refer to Table 10).

TABLE X. RESULTS ABOUT DOCUMENT DISPLAYING STYLES

Question: ***Which display format do you like better?***	***Numbers (Total 25)*** ***Note: missing one response***
Click button to read each page of an article	13
Moving avatar and than reading each page of an article	12

B. *Student's Feedback and Evaluation*

We did not conduct a formal qualitative analysis of student comments. We aim to categorize the students' post-survey perceptions, insights, and opinions to add qualitative commentary to the study. These comments complement the descriptive analysis from the student surveys. Despite the lack of a qualitative research methodology, these student comments can serve as additional information for the next iteration of this research.

The question, "Your overall feedback and feeling about learning from watching a lecture video in the metaverse? Please be specific." asks the students to describe what they feel about reading an article in the metaverse after the experiment. To analyze their responses, we defined specific categories under the UX measurement factors (e.g., positive desirability, perceived usefulness, etc.) and identified statements associated with these factors. We extract some examples from the results and put them into these categories as follows.

- Positive Desirability:

  "Very fun."

  "I thought it was overall more enjoyable than normally watching one."

- Distracting:

  "There is too much going in to be able to focus on any one thing, it's all way too distracting."

  "I was very easily distracted by cool new tech that the video contents were honestly secondary to the cool factor"

- Focused (Motivation to Attend):

  "Learning from a lecture video in the metaverse can be an immersive and engaging experience."

- Difficult-to-use:

  "There's also a curve of learning how to navigate and interact within the metaverse which might take time to get used to."

The question, “Your overall feedback and feeling about learning from reading an article in the metaverse? Please be specific,” asks the students to describe their feelings about reading an article in the metaverse after the experiment. We extract some examples from the results and categorize them as follows.

- Real-to-user:

  “Very real.”

  “It is a very involving experience”

- Positive Desirability:

  “It was more exciting to read…”

- Distracting:

  “Again I was super easily distracted by the VR aspect of it all.”

- Uncomfortable:

  “I felt like my eyes were melting with how bright it was.”

  “I felt bulky on my face.”

- Focused (Motivation to Attend):

  “I enjoyed it because there were less distractions and it was easier for me to pay attention to the topic.”

  “I like how it cuts out reality for a minute so you are more focused on the metaverse/”

  “Excellent engaging experience. Enjoy the isolation.”

C. Pros and Cons from Student’s Perspective

The pro and con question forces students to analyze the metaverse to learn from their perspective. This allows them to re-think again from the designer's view. We find many comments similar to the overall feedback on learning from videos and documents. Regarding the pro part, many students believe that the immersive and isolated environment allows them to view the materials without external disturbances. The metaverse lets them feel like a game and can add gamification factors. Students want to be more engaged with the metaverse courses. Regarding the con part, many students need help with the learning curve of using VR devices and controlling user interfaces or avatars.

VI. Discussion

A. Student’s Feelings toward Engagement

All students express enthusiasm for the learning activities in the metaverse, stating strengthened focus and perceiving greater benefits in learning within the metaverse, as evidenced by the average scores in the relevant questions (V-Q10, V-Q11, D-Q14, and D-Q15) in Table 9. Likewise, student feedback and comments provide insight into the underlying reasons for these ideas.

B. Video vs Document

From Table 8, both teams learn better by watching a video on a website. We argue that students cannot control video playing well. The average value on V-Q9 can support this. During the class component development, we understood that the permission design on the video was inappropriate. This also reflects the weak and complex user permission design of video controls. In addition, from their written feedback, students think that videos in the metaverse are a no-better learning tool than just watching the video on their computer. This might explain why watching videos in the metaverse is less effective than watching them on a browser.

Moreover, this discrepancy between the effectiveness of different content types within the metaverse could be attributed to the static nature of textual materials, which requires less spatial navigation and can be processed deeper due to reduced cognitive load compared to dynamic video content. In immersive environments, where sensory stimulation is high, static content might allow students to focus better by minimizing the cognitive demands required to navigate the content. The extraneous video demands may have increased cognitive load and distracted the student from concentrating on the essential content [21].

Table 8 also shows that both teams learn better by reading a document in metaverse than on a browser. However, students’ perceptions contradict their performance (see the average value in D-Q16). They think it is not better to read a document in the metaverse. We believe there are fewer page control issues. This discrepancy might be attributed to the novelty and unfamiliarity of the metaverse interface, which can initially increase the germane cognitive load as students adapt to a new learning environment.

Fig. 4. A Student Plays the Note Taking Tool without Focusing on Learning

Additionally, fewer page control issues were noted in the metaverse, which typically simplifies navigation but may have needed to be more sufficiently intuitive for all users. This aspect underlines the importance of interface design in educational VR applications, where ease of use must be balanced with engaging, interactive elements to harness the full cognitive benefits of immersive learning environments. Moreover, the newness and complexity of VR navigation might increase the effort required to learn how to use the technology. Additionally, it hints at the potential for improved interface designs to better support learning by reducing unnecessary cognitive load and enhancing user experience.

C. Focus vs Distracting

While the metaverse can engage students more deeply with the content, the very features that make it engaging can also introduce distractions. The extensive array of interactive tools and the expansive virtual spaces encourage exploration, which, while beneficial for learning through discovery, can divert attention away from structured learning tasks (see Fig. 4). To address these challenges, educational metaverses could incorporate design elements that help guide student interactions without curtailing the exploratory benefits of virtual worlds. However, training students on effectively using the metaverse for educational purposes is essential. This preparation should include strategies to manage their environment and maintain focus, ensuring that the immersive nature of the metaverse serves as a boon to their learning experience rather than a barrier.

D. Lesson Learned from Course Component Creations

Regarding our third research question, our investigation highlights instructors' notable difficulty in generating highly interactive content within a metaverse platform without programming. Student pro and con comments underline the importance of user-friendly interaction for effective learning. We propose three key considerations for course material or classroom creation within the no-code constraints during the development. Firstly, incorporating plenty of signs is crucial. Clear signs within the classroom can guide students to learning materials and essential controls, such as buttons for going to the next or previous page. Notably, signs are often required to display teleportation spots that move from one space to another because it is very helpful for users to grasp where to go quickly. Secondly, examining the scale or size of 3D objects, rooms, documents, or videos through a VR device is imperative. Since all metaverse platforms utilize web pages for virtual space editing, failing to assess the virtual space through VR may lead to user discomfort during learning. Lastly, we recommend employing a star topology rather than ring or mesh configurations for designing interconnected spaces, with the central hub serving as the primary entry point. This interconnected layout facilitates seamless navigation between satellite spaces and the hub, minimizing confusion and optimizing learner travel efficiency.

E. Limitations

The duration of our experiment was limited to just 20 minutes. This means that we only know the learning effects and efficiency within a brief time. Since our study was a one-time endeavor, we needed more information about the long-term impact of learning within the metaverse. Furthermore, our study materials were confined to computing-related subjects, potentially introducing bias regarding learning effectiveness. Our research design relied on surveys to gather participants' viewpoints and perceptions, and the data collected from just 26 students, all from Computer Science and Software Engineering programs, may be biased. We were interested in the respondent’s subjective experience of learning in the metaverse via a head-mounted device contrasted with conventional browser-based learning.

VII. Conclusion and Future Work

Our research reveals that the metaverse offers an isolated and immersive environment conducive to student focus on learning materials. Students find the learning experience enjoyable, exciting, and engaging within the metaverse. However, our findings indicate that learning via video in the metaverse is less effective than traditional browser-based viewing, primarily due to difficulties in video manipulation affecting outcomes. These insights can guide instructors in preparing course content within existing metaverse platforms and remind developers to design metaverse or virtual reality platforms tailored for educational purposes.

The metaverse presents numerous opportunities to fascinate students and enhance learning experiences. Yet, the quality of interactions remains a critical determinant of learning efficiency. Therefore, future works may focus on developing more intuitive hardware and software interfaces to explore their impact on learning outcomes. Additionally, investigating student learning across various subjects could further deepen our understanding of leveraging the metaverse as a learning tool in the future.

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