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PAPER

Empirical Studies on the Metaverse-Based Education: A Systematic Review

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ABSTRACT

The Metaverse is a digital space achieved through a virtual environment that allows people to enjoy immersive experiences and interactions. The Metaverse is changing the world in different fields, from education to health. However, using the Metaverse for educational purposes has rarely been discussed. While there are only a few reviews summarizing the findings of studies on the Metaverse, no study has systematically analyzed empirical studies of the Metaverse in education. This study presents a systematic review of empirical studies on Metaverse-based education to fill this gap. The results revealed that empirical studies were conducted with university students, but no study focused on middle and primary school students. The results showed that virtual reality is the most common Metaverse type used in empirical studies. However, there is a need for empirical work using mixed-reality technology in the educational Metaverse. As a result of examining the student engagement findings in the studies included in the review, it was seen that few experimental studies focused on students' behavioral engagement. It is expected that the findings of this study will guide empirical research on the Metaverse in education.

KEYWORDS

emprical study, metaverse, metaverse in education, systematic review

1 INTRODUCTION

The concept of the Metaverse, which was first mentioned in Neal Stephenson's novel *Snow Crash* (1992) [1], is used today to describe a three-dimensional virtual world in which real people exist with their avatars [2]. It is also expressed as virtual structures in which individuals interact through avatars to redesign real life in a virtual environment without space and time constraints [3].

In the past two decades, Metaverse tools have taken a significant place in our lives [4]. However, the popularity of the concept of the Metaverse gained momentum in 2021 when Facebook CEO Mark Zuckerberg [5] announced that he was

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rebranding the company under the name Meta and introduced the institution's breakthroughs related to the Metaverse [6].

Metaverse is also a concept introduced previously in education because many researchers discussed its effects on learning. To elucidate, Barry et al. [7] investigated the effect of problem-based learning education in the virtual world on learning in two different student groups, one in Japan and the other in America. The research results showed that both groups of students were satisfied with being in the Metaverse environment in the classroom. Ahmad et al. [8] developed a course module on health education in the virtual world of Second Life and implemented it with students. As a result of the research, most students stated that working with a virtual-reality program was safer, interactive, less tedious, and easier to remember than experimenting on real patients. They also emphasized an alternative study option for distance health education students. González and Blanco researched the design and use of educational video games based on the online role-playing game engine in virtual worlds. They reported that educational video games support the development of technical and social skills in the real world, support learning by increasing motivation, and contribute to social learning [9]. Quintana and Fernández [10] developed a model in the virtual world for the pedagogical education of teachers in training and conducted a study on the achievements in teacher education. At the end of the application, these pre-service teachers emphasized that although there were some difficulties in using the platform, the experience they gained allowed them to be supportive and motivating, and to strengthen the subject content throughout their teaching practice. Kanematsu [11] analyzed the relationship between students by measuring their biological data, such as blinking and facial temperatures in e-learning environments, and also by tracking their psychological behaviours. It was found that the students' emotional reactions corresponded to the number of blinks, as they could answer the questions asked in the videos very quickly. Tang [12] organized a game platform and digital library exercise activity for university students using augmented-reality technology. Then, the feedback from the students was evaluated. Students stated that this game was informative and creative and that the augmented-reality game helped them get to know the library areas, services, and subject librarians.

A summit was held at the Stanford Research Institute International to chart a roadmap for the future of Metaverse technology in 2006. Interviews were conducted with futurists, technology architects, academics, and entrepreneurs who attended the summit to conduct a study on a 10-year technology forecast and vision research. After the conference, the Metaverse Roadmap Report was prepared [13].

In their Metaverse Roadmap report, Smart, Cascio, and Paffendorf [14] defined the Metaverse world as *augmentation* versus *simulation*, and *internal* versus *external*.

These axes represent four dimensions with overlapping technologies: virtual worlds, mirror worlds, life logging, and augmented reality. In order to understand these categories and the relationships between them, it is crucial to examine the axes (Augmentation – Simulation – Internal – External).

By superimposing digital information on the real world, augmented-reality technology gives the existing environment a new visual function.

Simulation technology creates a virtual experience by modelling the physical environment and creating a virtual environment [14–15].

The internal world can be explained as identity-oriented technologies. It employs technology that focuses on the identity and behaviour of people or objects by building the interiors of avatars or digital profiles that users have within the digital environment.

The external world focuses on the environment and the world. In the context of the Metaverse, these technologies provide information and control about the user's environment.

Smart [14] proposed four categories and dimensions for the Metaverse based on the relationship between the axes (Figure 1).

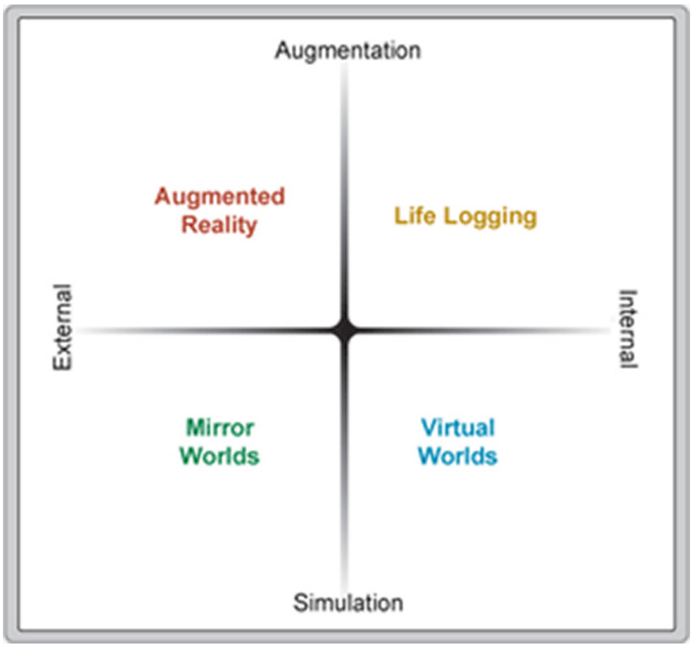

Fig. 1. Categories and dimensions for the metaverse

Virtual Worlds along the Internal and Simulation axes models reality and imagination in virtual environments. Simulations allow individuals to have a second identity in the virtual world [16]. Second Life, Roblox, and Minecraft are the best-known examples of this dimension [17].

Mirror Worlds along the External and Simulation axes models the world around us. It includes advanced virtual mapping, modelling tools, sensors, and location-aware technologies. The best-known mirror-world examples are Google Earth and Google Maps [17].

Augmented Reality along the External and Augmentation axes adds virtual information to our physical world; its contents are better understood, learned, and perceived. The Pokemon Go game is a perfect example of this dimension [17].

Life Logging along the Internal and Augmentation axes includes technologies that record people's past or current status information and memories. Apps like Instagram, Facebook, Apple Watch, and Samsung Health fall into this category [17].

Virtual-reality and augmented-reality technologies are used in many fields of education to activate educational processes. With the spread of immersive technologies, including augmented reality (AR), virtual reality (VR), mixed reality (MR), and extended reality (XR), many studies have been conducted on the effects of these technologies in the field of education. In addition, extended reality (XR), which combines augmented reality and virtual reality, is another technology that provides a virtual-learning experience by performing learning activities in controlled environments [18].

Immersive technologies in educational environments contribute positively to students' motivation, analytical skills, and performance [19, 20].

According to Henderson and Feiner [21], combining real and virtual objects in three dimensions helps reduce students' cognitive load. The users' senses do not directly perceive the displayed virtual objects, and augmented-reality applications can improve the user's perception of and interaction with the real world. One study stated that virtual reality technologies used in educational environments help student learn and maintain their learning [22].

According to the literature research conducted within the scope of the study, no study has yet examined empirical studies on the effects of using Metaverse technologies in education or summarized the findings of the studies to guide future studies. Therefore, the present systematic review aims to identify significant research gaps by analyzing empirical studies on the Metaverse in education. The research questions guiding this review are as follows:

a) What are the descriptive features of the Metaverse studies in education (year of publication, country, research methods, subjects, and participants)?
b) What technologies and tools of the Metaverse are most used in the education domain?
c) What are the main features of student engagement (in behavioural, cognitive, and affective dimensions) in the empirical research on the Metaverse in education?

2 STUDENT ENGAGEMENT

According to Groccia and Hunter [23], student engagement is multidimensional and encompasses various campus activities beyond students' learning behaviors inside and outside the classroom. Effective learning requires situations that overcome real problems, allow the course content to be applied to these problems, and provide learning experiences that lead to continuous intellectual development and a high sense of personal responsibility.

To achieve a satisfactory result in learning, a student must participate in the learning process on the levels of behaviour, affect, and cognition. For participation at the behavioral level, there must be student involvement or effort, and the student must be tenacious in the pursuit of knowledge. The student must be interested in the experience to the point that the learning increases motivation and enjoyment to reach the level of emotional engagement, thereby establishing a level of engagement. Finally, the student should be engaged at the cognitive level, exhibiting mental activity, and be able to process the experience cognitively and make connections with the previous [24]. Engagement requires not only participation or involvement but also emotions and meaning [25]. A study [26] explained the three dimensions of student participation as follows:

- Behavioural engagement: Students typically engage in norms of behaviour such as attendance and involvement and demonstrate the absence of negative behaviours.
- Cognitive engagement: Students are invested in learning, seeking to go beyond the requirements and enjoying the challenge.
- Affective engagement: Students who are emotionally engaged respond emotionally, such as experiencing interest, pleasure, and a sense of belonging.

3 METHODOLOGY

This research conducted a systematic review based on predetermined criteria and followed the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analysis) reporting guidelines [27] to reveal the effect of the Metaverse in the field of education.

3.1 Search strategy

In order to identify relevant studies, articles published in SpringerLink, Scopus, Elsevier, IEEE Xplore, and Google Scholar databases were searched. These databases were chosen because they include journals on an extensive range of educational technologies. Searches for the Educational Metaverse included empirical studies published from January 1, 2018, to September 1, 2022. The initial search was carried out according to Boolean logic as follows: "Metaverse" AND "education" (OR "teaching" OR "learning" OR "student" OR "teacher" OR "school" OR "university").

3.2 Study selection

Inclusion and exclusion criteria were used to decide whether to include articles selected from database searches (Table 1). The inclusion criteria and exclusion criteria were as follows:

- *Inclusion:* Empirical studies written in English published in journals or conferences, that used Metaverse technologies and measured student involvement were included. Studies that did not explore or report an aspect of student participation according to the identified indicators were excluded.
- *Exclusion:* Studies that did not focus on the research objectives of this study, previous versions of a published article that explored the same aim using the same dataset, and studies that developed only one tool and did not evaluate that tool in a learning setting were excluded. Also, nonprimary studies (e.g., books, theses, and systematic reviews) were excluded.

Table 1. Inclusion and exclusion criteria

Inclusion Criteria	Exclusion Criteria
• Published 2018–2022* • Written in English • Used Metaverse echnologies • Empirical studies	• Published before 2018 • Not in English • Metaverse technologies not used • No learning settings

Note: *September 1, 2022.

The method for selecting the relevant publications is shown in the PRISMA flowchart in Figure 2.

The initial search yielded 126 records. These records were from SpringerLink (n=58), Elsevier (n=34), IEEE Xplore (n=19), and Google Scholar (n=15). In the first step, 53 duplicated articles were removed. Then the abstract and titles of the remaining 73 records were screened. Based on screening, 57 records were excluded, of which 35 excluded studies were not empirical, 19 did not use Metaverse technologies in educational settings, and 3 were not written in English. The remaining 16 records were checked for full-text availability, and 5 records were excluded because their full texts were unavailable. Thus, 11 records were included in this systematic analysis. Microsoft Excel was used for the analysis of full-text articles.

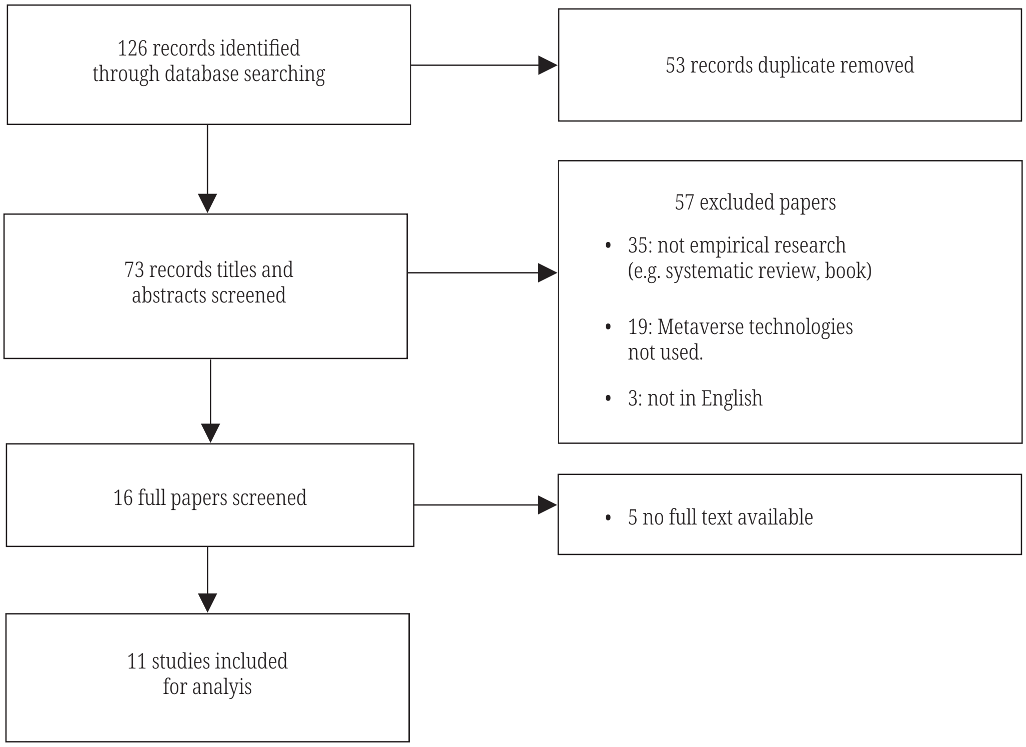

Fig. 2. PRISMA flowchart adapted from Brunton et al. [28]

3.3 Data extraction and analysis

The coding method developed and used by Bond et al. [29] was adapted and used to extract the study data. Codes included article information (e.g., year of publication, country), participant education level, research methods, subject, Metaverse technologies, and tools used.

Additionally, student engagement was coded under cognitive, emotional, or behavioural engagement, defined based on a literature review.

4 RESULTS

In this section, the findings related to the study's research questions were explained in order.

4.1 What are the descriptive features of Metaverse studies in education (year of publication, country, research methods, subjects, and participants)?

Publication year. Most empirical studies (8 out of 11) were published in 2022, 2 in 2021, and 1 in 2020. It was determined that empirical studies were not conducted in 2018 and 2019 (Table 2). The sharp increase in Metaverse studies in education in 2022 may be because many companies and even states have announced their Metaverse strategies, with Facebook changing its name to Meta [6].

Country. Most studies originated in South Korea (4 out of 11). Two studies were conducted in Thailand, 2 in the USA, 1 in Mexico, 1 in Serbia, and 1 study in multiple European countries. The studies are predominantly in South Korea because, after the start of COVID-19, the South Korean government motivated 500 companies to work in the Metaverse field and carried this out with a national strategy [30].

Research methods. As seen in Table 2, the most frequently used method in studies is the quantitative method, with 5 studies. Three studies used the case-study method, and 2 used the experimental method. There was only 1 study using the mixed method.

Subject areas. The subject areas of the studies were geography (n=1), aircraft maintenance technical education (n=1), engineering education (n=1), English education (n=1), mathematics (n=1), digital media (n=1), teaching lab program (n=1), multimedia (n=1), agriculture (n=1), medical education (n=1) and librarianship (n=1). In addition, one study did not specify the subject.

Participants. The education level of the respondents ranged from elementary school students to university students and teachers. Most studies were conducted with university student participants (8 out of 11). One study was conducted with middle school students, and 1 study was conducted with high school students. In 2 of the studies conducted with university students, there were educators as participants along with the students. In one of these two studies, farmers and technical staff were also included as participants. One study reported its participants as Millennials and Gen Z. However, none of the studies included primary school students as participants. The results reveal that there is a need for studies with high school and primary school students.

Table 2. Descriptive features of empirical studies

Study No.	Publication Ear	Country	Methodology	Participants' Education Level	Subjects
1	2020	Mexico	Quantitative	High school students	Mathematics
2	2021	Thailand	Experimental	University students	Unspecified
3	2021	USA	Case Study	University students	Librarianship
4	2022	Serbia	Quantitative	Millennials and Gen Z	Geography
5	2022	South Korea	Mixed	University students	Aircraft maintenance
6	2022	South Korea	Case study	University students, teachers	Engineering
7	2022	South Korea	Quantitative	University students	English education
8	2022	USA	Quantitative	University students	Digital media
9	2022	South Korea	Quantitative	University students	Teaching lab program
10	2022	European countries	Experimental	Middle School students	Multimedia
11	2022	Thailand	Case study	Teachers, university students, technology section staff, farmers	Agriculture

4.2 What types and tools of the Metaverse are most used in the education domain?

The Metaverse types and tools used by the included studies were analyzed (Table 3). While coding the Metaverse types used in the studies, the classification method of Kye et al. [17] was taken as a basis.

Metaverse types were divided into four categories: platforms, wearable technology, simulations, and immersive. Immersive technologies are classified into three categories: augmented reality, virtual reality, and mixed reality (Figure 3).

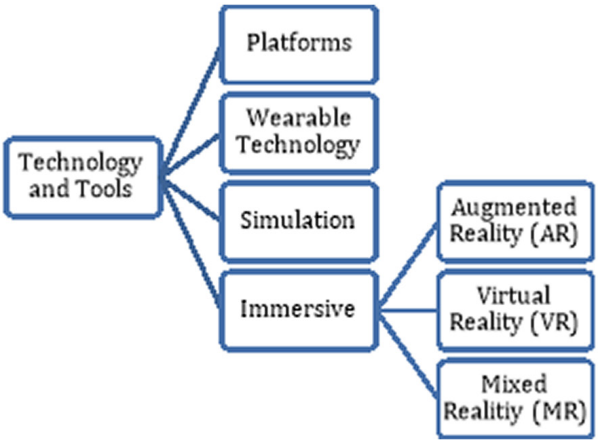

Fig. 3. Metaverse technologies and tools used in studies

Table 3. Metaverse types and tools used in selected studies

Study No.	Metaverse Type	Tools
1	Immersive AR	AR applications in app store (macOs) and play store (Android) virtual stores
2	Immersive VR and platform	Metaverse embedded on learning management system, virtual class
3	Immersive AR	AR library treasure hunt game
4	Platform	VoRtex Metaverse platform, VR
5	Immersive VR	Aircraft maintenance 3D simulation
6	Immersive VR	Virtual class
7	Immersive VR, AR	Cospaces Edu (VR maker), frame VR (Metaverse platform), VR contents, digital textbook (3D learning contents)
8	Immersive VR	Oculus Horizon Workrooms, video conferencing, spatial audio, Virtual class
9	Immersive VR	VirBELA (V-story) platform
10	Immersive VR	3D HMD, 2D video, 2D video head-mounted display (HMD)
11	Platform and simulation	3D simulation, LMS system, smart mobile devices, computers

Metaverse types and tools. The studies examined determined that the most common type of Metaverse (8 out of 11) was immersive VR technology (Table 3).

In one of these studies, immersive VR and platform types were used together (Study 2). In another study, immersive VR and AR technologies were used together

(Study 7). It has been determined that 2 studies used only AR technology (Studies 1 and 3). There was 1 study where Platform and Simulation types were used together (Study 11).

Students' immersive experiences in the Metaverse educational environment positively affect skills development and collaboration [31]. A study shows that VR technologies increase student acceptance receptivity and student learning rates [32]. This finding supports studies reporting that immersive VR is the most actively used Metaverse type [17, 33]. Additionally, the consensus is that VREs enhance students' participation and involvement in learning activities [34].

When we looked at the tools used in empirical studies, it was determined that 5 studies used the platform (Studies 2, 4, 7, 9, and 11), 3 studies used VR class (Studies 2, 6, and 8), and 2 studies used 3D simulation (Studies 5 and 11). Only AR apps were used in 2 studies (Studies 1 and 3). Only 1 study used wearable technology (Study 10). The review reveals that most studies are about Metaverse platforms and immersive technologies.

This finding is not surprising, considering that learning scenarios have become attractive to students and teachers, thanks to the use of Metaverse platforms, and are also ideal for teaching and learning processes [35]. Wearable devices and sensors help teachers monitor student dynamics by analyzing student behaviour. For example, thanks to smart glasses, teachers can analyze students' emotional reactions according to the number of blinks [36]. However, the reason that wearable technologies are not widely used may be due to their high cost [37].

4.3 What are the main features of student engagement (in behavioural, cognitive, and affective dimensions) in the empirical research on the Metaverse in education?

In order to find an answer to the study's second research question, student participation was examined from behavioural, cognitive, and affective dimensions, and the basic features of student participation from these three dimensions were determined.

Cognitive engagement. The most frequently measured dimension of engagement was cognitive engagement, with eight different indicators identified (Table 4).

Table 4. Student cognitive engagement indicators

Indicators	Study Number
Learning	Study 1, Study 5, Study 11, Study 3
Academic performance	Study 1, Study 8, Study 2
Retention	Study 1, Study 11
Creativity	Study 7, Study 3
Motivation	Study 1
Critical thinking	Study 7
Concentration	Study 6

The most cited cognitive engagement increase was learning (Studies 1, 3, 5, and 11) and academic performance (Studies 1, 2, and 8). It has been reported that Metaverse technologies used in these studies positively affect students' academic performance and learning.

The reviewed studies reported that it positively affected the retention of knowledge (Studies 1 and11). A study [22] stated that virtual reality offers an innovative approach to encouraging learning and retention.

Two studies reported that Metaverse technologies positively affected students' creativity (Studies 3 and 7).

One study (Study 1) reported that students' motivation increased in educational environments using Metaverse technologies. One of the reviewed studies reported that it had a positive effect on students' critical thinking (Study 7). In addition to the positive effects, 1 study reported difficulties in students concentrating (Study 6).

In light of all these findings, it can be said that the Metaverse technologies of the study have a positive effect on the students' cognitive engagement. Parallel to this study finding, there are studies stating that Metaverse environments contribute to learning [38, 39] and increase motivation [20, 40].

Affective engagement. The studies reviewed found five leading indicators of student affective involvement (Table 5).

Table 5. Student affective engagement indicators

Indicators	Study Number
Attitude	Study 6, Study 1, Study 9, Study 3
Interest	Study 4, Study 10
Enjoyment	Study 9, Study 10
Satisfaction	Study 1

In the studies, it was determined that student's opinions about the experiences in the Metaverse environment were sought, the effect of virtual environments on learning outcomes was investigated, and students' attitudes towards and satisfaction with the virtual environment were evaluated (Studies 1, 3, 6, and 9).

Some studies reported that students' interest in subject content and learning was positively affected (Studies 4 and 10), while others reported that students' enjoyment led to engagement (Studies 9 and 10).

In one study, students said that Metaverse technologies made learning satisfying (Study 1).

In parallel with this research finding, a study [41] reported that the visual presentation of the content in the Metaverse virtual worlds arouses the curiosity of the individuals and that learning becomes fun—and thus participation increases. Despite existing literature indicating that virtual worlds enhance student engagement [42, 43, 44], further research is necessary.

Behavioural engagement. In the reviewed studies, the least measured dimension of engagement was behavioural engagement, with three different indicators (Table 6).

Table 6. Student behavioural engagement indicators

Indicators	Study Number
Participation	Study 8, Study 10
Digital skills development	Study 8, Study 11
Collaboration	Study 7

Two studies reported that Metaverse educational environments increase student participation (Studies 8 and 10). The reviewed studies found that students positively affected technology adoption (Study 8) and increased their ability to use a laptop (Study 11). Also, there is a study reporting that students have a positive effect on collaboration (Study 7). Only four studies (Studies 7, 8, 10, and 11) measured student behavioural engagement. Therefore, more studies measuring students' behavioural engagement are needed.

5 LIMITATIONS OF REVIEW

This review search was limited to four main databases; SpringerLink, Scopus, Elsevier, IEEE Xplore, and Google Scholar. Also, this study was based on only three dimensions of student participation: behavioural , cognitive, and affective. In future studies, different sources and other dimensions can be used. Additionally, a similar review of other types of literature, including articles and theses published in languages other than English, may be helpful.

6 CONCLUSION

This study analyzed the current state of empirical research on using Metaverse technologies. Metaverse technologies have brought a new perspective to education processes and have positively affected education and training. These environments, which provide new educational opportunities and contexts for students, make possible many educational programs or goals that cannot be reached in the real world, thanks to the Metaverse. From an educational perspective, it is essential to consider potential learning and curriculum designs in the Metaverse world. However, low-cost equipment is required that enables students to interact with high-quality digital content with Metaverse tools. For most people, the cost of associated equipment (e.g., head-mounted technology) is still high.

Using Metaverse technologies is essential but not a sufficiently empirically researched subject. Thus, empirical research should be conducted on applying Metaverse technologies in education. Additionally, the importance of student engagement in Metaverse-based learning and the characteristics of the dimensions of engagement (behavioural, cognitive, and affective) have been identified. It is thought that this systematic review will make an essential contribution to the literature investigating how Metaverse technologies affect all three dimensions of student participation.

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