The Metaverse – The Next Big Thing in Education: A Systematic Literature Review

RESEARCH ARTICLE

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Abstract

Metaverse utilization in education is an area with a huge potential of development during the current age of technology innovation. Using a PRISMA-adapted methodology, we performed a qualitative systematic literature review of the main scientific production related to metaverse in education. We analyzed 48 academic papers and formulate six research questions. We discovered that, despite fertile, the research area is in its early stages of development and there is a need for more quantitative analyses. We grouped the paper keywords into five categories, which are virtualization, education, technology, library, research and others, and identified seven major themes from the findings of the papers: (i) the place of the metaverse in education in general, (ii) the possible implementations of the metaverse into different courses, (iii) the direct instructional support of the metaverse in education, (iv) the indirect instructional support of the metaverse in education, (v) the variables/conditions of a successful metaverse implementation in education, (vi) the possible challenges of metaverse in education, (vii) encouraging research regarding metaverse in education. Finally, we proposed a more comprehensive definition for the metaverse, discussed potential extensions of metaverse in education and possible threats, and presented the main implications from research, policy and practical perspectives.

Keywords: *metaverse, systematic literature review, education, instruction, teaching*

Metaverse - Eğitimde Bir Sonraki Büyük Şey: Sistematik Bir Literatür Taraması

Öz

Eğitimde Metaverse kullanımı, içinde bulunduğumuz teknoloji inovasyon çağında büyük bir gelişme potansiyeline sahip bir alandır. PRISMA'ya uyarlanmış bir metodoloji kullanarak, eğitimde metaverse ile ilgili temel bilimsel üretimin niteliksel sistematik bir literatür taraması uygulanmıştır. Kırk sekiz akademik makale incelenmiş ve altı araştırma sorusu oluşturulmuştur. Verimli olmasına rağmen, araştırma alanının gelişiminin ilk aşamalarında olduğunu ve daha nicel analizlere ihtiyaç olduğunu görmekteyiz. Makale anahtar kelimelerini sanallaştırma, eğitim, teknoloji, kütüphane, araştırma ve diğerleri olmak üzere beş kategoride gruplandırılmış ve makalelerin bulgularından yedi ana tema belirlenmiştir: (i) metaverse'nin genel olarak eğitimdeki yeri, (ii)) metaverse'nin farklı derslere olası uygulamaları, (iii) metaverse'nin eğitimde doğrudan öğretim desteği, (iv) metaverse'nin eğitimde dolaylı öğretim desteği, (v) başarılı bir metaverse uygulamasının değişkenleri/koşulları eğitim, (vi) eğitimde metaverse'nin olası zorlukları, (vii) eğitimde metaverse ile ilgili araştırmaları desteklemek. Son olarak, metaverse için kapsamlı bir tanım önerirken, metaverse'nin eğitimdeki potansiyel uzantılarını ve olası tehditleri tartıştık ve araştırma, uygulama ve politika perspektifinden ana çıkarımları sunulmuştur.

Anahtar Kelimeler: *metaverse, sistematik literatür taraması, eğitim, öğretim, öğretme*

Introduction

Merriam-Webster describes the Metaverse (Merriam-Webster, 2021) as "a highly immersive virtual world where people gather to socialize, play, and work". Similarly, Siyaev and Jo (2021) claim that metaverses will have a crucial role in the industry, as well as in many other activities, such as education, culture, entertainment and communication. Virtual experiences associated with the Metaverse are enabled by various types of intertwined technologies, such as: virtual reality (VR), augmented reality (AR), mixed reality (MR), 3D representations, artificial intelligence (AI), machine learning, deep learning (Siyaev and Jo, 2021), 5G, big data, ubiquitous computing, and digitalization (Fanea-Ivanovici and Pana, 2020).

The Metaverse has also started to have an impact in education, which has been more obvious in the pandemic context (Siyaev and Jo, 2021). Nonetheless, the idea of virtual or immersive learning environments had existed well before the COVID-19 pandemic, and they were designed to facilitate learning beyond geographical or cultural boundaries (Ayiter, 2008) and to provide more learning and information opportunities (Sidorko, 2009). Virtual worlds like the Second Life also serve educational

purposes in libraries through investment in virtual content (Sidorko, 2009) and under conditions of accessibility, security and sustainability (Hill and Lee, 2009). Avatars, Second Life classroom experience, Second Life URLs, Second Life groups, immersive learning environments, notecards, machinima ('machine' and 'cinema'), digital exhibits, live presentations, web links, virtual library services, virtual field trips are just a few of the methods proposed for inclusion of the Metaverse in education (Hill and Lee, 2009).

Due to the development of teaching tools and environments beyond the real (as opposed to virtual) setting, education at higher levels is no longer a high-end destination for just a few in the 'Ivory Tower', who are enrolled in formal education, but content becomes available to many more, in multiple formats and environments (Abeles, 2007). The virtual environment can speed up the learning process through technology, which can make the shift from the physical world to the Metaverse. Here, students can even skip some of the traditional education sequences (Abeles, 2007).

The aim of this study is to perform a systematic literature review of the most prominent research in the field of education metaverse based on an adapted PRISMA methodology.

Literature review

Technological developments have led to the popularization of 3D virtual environments for education and to a decrease in the costs associated to them (Chau et al., 2013; Chen, 2022). The challenges of successfully implementing social virtual worlds for teaching and learning and for democratizing technology-enhanced instruction are threefold: to design the courses, to implement the practice and to identify the specific needs of student community (Steils, Tombs, Mawer, Savin-Baden, and Wimpenny, 2014). The main points of interactive and virtual learning experience in higher education are games, VR, 3D identities, interactive communication, customized teaching models, disciplinary learning, and institutional space and ownership (Chen, 2022; Wimpenny, Savin-Baden, Mawer, Steils, and Tombs, 2012).

Second Life is an early-stage instance of the Metaverse applied in education. The impact of Second Life inclusion in higher education courses was assessed by Schiller, Goodrich, and Gupta (2013) on marketing courses taught to undergraduate students. Their research indicates that students find learning in a Second-Life environment to be more effective, due to its game-like and easy-to-use character, but also thanks to the active learning principle used (i.e., learning by doing).

Virtual education settings can improve the outcomes of education in fields where practice is required. This can be achieved through simulations. Such is the case of

healthcare education, where a study on Second Life undergraduate nursing research revealed the importance of transfer from theory to practice, the learner-centered approach and the evaluation in such context (Irwin and Coutts, 2015). Competitive game-based learning was used to evaluate the learning outcomes among medical students in radiology, and it was revealed that it is both effective and well accepted (Lorenzo-Alvarez, Rudolphi-Solero, Ruiz-Gomez, and Sendra-Portero, 2019).In the same vein, Jarmon, Traphagan, Mayrath, and Trivedi (2009) acknowledge that 3D virtual worlds can be suitable for experiential learning environments, although their study was conducted on graduate studies in interdisciplinary communication. This is because practice in virtual environments does not imply risks (e.g., in medical school, risks for learners and patients) (Pasquier, Gaudry, Tesniere, and Mignon, 2015). Other areas of application of the Metaverse in education are blended learning, language learning and competence-based education, according to Zhang et al. (2022). Wang et al. (2022) posit that the 'edu-metaverse' is an ecosystem that comprises four major hubs: 1) instructional design and performance technology hub; 2) knowledge hub; 3) research and technology hub; and 4) talent and training hub.

Due to the risk-free environment, virtual reality settings in science education come with various benefits, such as learning, skills and safety behaviors similar to those in real-life laboratories, while allowing more time for learners to reflect on the new knowledge and content, rather than displaying clean-up behaviors (Hu-Au and Okita, 2021).Insofar as pre-university education is concerned, research has focused on the educators' experience with Active Worlds Educational Universe and Second Life, as vectors for the integration of new technologies in the teaching process (Dickey, 2010). The instructors' experience is particularly important due to their triple role of learners of applications, designers of syllabus and content, and evaluators of the benefits thereof. Dreamson and Park (2023) studied the school space design for metaverse-based learning and found that collaborative learning, interconnectivity, co-participation and transdisciplinary research should be articulated to create a metaverse-based learning framework.

Despite the numerous benefits of virtual environments for learning, the current literature discloses several shortcomings attached to such learning practices. For instance, a decrease in face-to-face communication because of virtual communication was reported by the students at Ajman University in the United Arab Emirates (Elsayed, 2020). Moreover, communication with the teaching staff is also affected, whereas other interaction issues have been reported (Chen, 2022). On a different note, personal data exposure and the lack of caution in virtual communication are other threats the respondents provided. Content production, game addiction and ethical concerns add

to the list of metaverse education shortcomings (Chen, 2022). Based on the study, Elsayed (2020) identifies possible solutions to these issues, such as sustained effort on behalf of learners and university to reduce virtual communication, raising awareness as to these menaces in the university classes and having non-virtual leisure time activities.

Zeide and Nissenbaum (2018) argue that platforms that are governed by marketplace norms have the potential to undermine some of the functions and values of traditional education (e.g., democracy, equal chances) due to the collection of data and automated instruction. Once again, data privacy is deemed an important shortcoming of virtual learning platforms. Furthermore, the learning process would exacerbate inequalities, despite its objective to provide inclusive education (Zhang et al., 2022). Although immersive learning is especially attractive for young learners, its implementation faces numerous barriers in higher education (Kshetri, Rojas-Torres, and Grambo, 2022).

From a macro approach, the gap between the information-rich and the information-poor can become larger (i.e., digital divide), which would further marginalize those not properly equipped with tools and skills (Oladokun and Aina, 2011). Hence, technology development difficulties may arise, thus increasing inequalities (Chen, 2022).

This preliminary study will be a source of information for educators who use or plan to use metaverse platforms in education to better understand the new dynamics. In this paper, instructional stakeholders will be able to identify the problems, solutions, risks and contributions of the metaverse utilization in education. Moreover, researchers can identify the existing gaps for further studies and practices. Therefore, the research questions of this study are stated as follows:

1: What is the yearly distribution, number of pages and number of cited references of metaverse in education-related papers?

2: What are the main categories of keywords in the selected documents?

3: What are the sampling methods of metaverse in education-related papers?

4: What are the educational levels of metaverse implementation in the selected papers?

5: What are the research methods of metaverse in education-related papers?

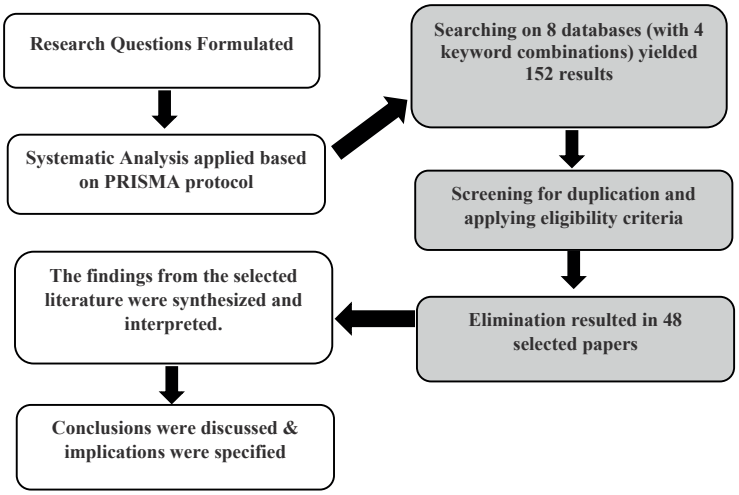
6: What are the main themes/categories of metaverse in education-related documents?

Method

To answer the above-mentioned research questions, the researchers employed an adapted PRISMA protocol version of Camilleri and Valeri (2021) to extract systematic literature on the topic of metaverse in education. Since metaverse is a relatively new topic, which has only recently produced real life implementations, it is clear that more research is needed. To serve as a basis for the prospective research studies and to unfold what work has already been produced, systematic literature review offers an effective research framework (Webster and Watson, 2002). Figure 1 shows the steps of the systematic literature review of this study:

Figure 1

Steps of Systematic Literature Review



The researchers identified four general education-related keyword combinations, each including 'metaverse': 'Metaverse + Education', 'Metaverse + Learning', 'Metaverse + Teaching' and 'Metaverse + Training'. These four combinations were applied on eight databases separately: Science Direct, Sage, Emerald, Wiley Online Library, EBSCO, JSTOR, Oxford Academic and Brill. As a result, the researchers downloaded all 152 papers and moved to screening for duplication removal and eligibility criteria application phases.

The researchers applied the following eligibility criteria on the full texts: relevance to education (including official schooling and work training), coverage of metaverse in the full text, publication in English language. As the metaverse is a very new topic, the researchers did not apply any historical filter on their searches.

Table 1

Number of Papers Before and After Elimination by Database

Database Name	Initial Number of Papers	Filtered Number of Papers
Science Direct	59	22
Sage	35	9
Emerald	25	9
Wiley Online Library	9	5
EBSCO	4	3
JSTOR	10	0
Oxford Academic	8	0
Brill	2	0
Total	**152**	**48**

Table 2

Journals Included in the Final Dataset

Journal Name	n	Journal Name	n
Procedia Computer Science	11	Journal of Enabling Technologies	1
Journal of Educational Computing Research	4	Journal of Special Education Technology	1
Computers & Education	3	Journal of Transformative Education	1
On the Horizon	3	Library Hi Tech	1
British Journal of Educational Technology	2	Library Hi Tech News	1
Journal of Educational Technology Systems	2	Library Management	1
Annual Reviews in Control	1	Library Review	1
Computer Animation and Virtual Worlds	1	Pixel-Bit. Media & Education Journal	1
Computers in Human Behavior	1	Procedia - Social and Behavioral Sciences	1
Creativity and Innovation Management	1	Procedia Technology	1
E-Learning and Digital Media	1	Sensors	1
Energy Procedia	1	Technoetic Arts	1

Expert Systems with Applications	1	Technological Forecasting & Social Change	1
Health Information and Libraries Journal	1	The Journal of Academic Librarianship	1
Interactive Technology and Smart Education	1	Total	48

After the elimination process, the researchers retained 48 papers for further analysis. The full reference list of these 48 articles is provided in Appendix 1 of the article. Table 1 shows the number of papers for each database, before and after the elimination. Table 2 presents the title of the journals where the 48 papers were gathered.

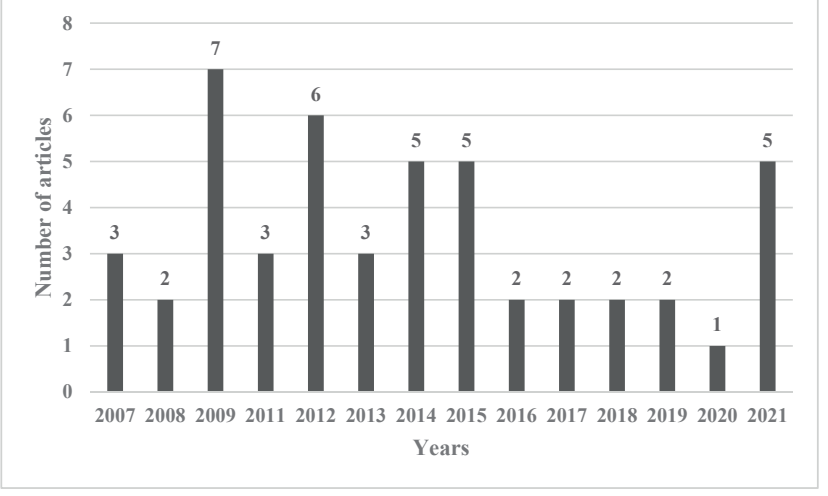
The researchers reviewed all 48 full-text papers and conducted manual qualitative content analysis to address the major research questions and to reveal the main themes appearing in the dataset.

Results

Figure 2 below presents the yearly distribution of the papers published on the topic of metaverse in education.

Figure 2

Yearly Distribution of the Selected Papers



The number of papers published in this area is relatively low and these publications are recent. The first paper was published in 2007, and the trend in publication has not increased significantly.

Table 3

Number of Pages for Selected Documents

Number of pages	n	Number of pages	n	Number of pages	n	Number of pages	n	Number of pages	n
4	4	8	3	13	2	18	2	26	1
5	1	9	1	14	2	20	1	27	1
6	2	10	9	16	1	21	3	33	1
7	5	12	6	17	1	23	1	35	1

The number of pages of the full-text papers vary from 4 (n=4) to 35 (n=1). Table 3 indicates the number of pages for the papers included in the dataset.

In addition, the researchers checked the total number of cited references used in the 48 papers. The minimum is 1 article and the maximum is 99 articles, whereas the average is 33 articles with a standard deviation of 23 articles.

To answer the second research question, the researchers gathered all the keywords from the 48 documents, which is significant for identifying the type of technologies mentioned in the 48-article dataset. All 200 keywords of the 48 articles were examined by manual qualitative content analysis method. The keywords were grouped in the following six categories: virtualization, education, technology, library, research and others.

Table 4

First Broad Category of Keywords

Keyword	n	Keyword	n	Keyword	n	Keyword	n
Virtual World	5	3D Virtual World	2	Virtual Community	1	3D Virtual Environment	1
Virtual Reality	2	3D Environment	2	Virtual Learning Environment	1	Virtual Environment	1
Virtual Class	2	Virtual Work	1	Virtual Design Architecture	1		

The first broad category is about virtualization and 3D immersion (Table 4) where ‘virtual world’ was the most common keyword (n=5).

Table 5

Second Category of Keywords

Keyword	n	Keyword	n	Keyword	n	Keyword	n
Active Learning	4	Community of Inquiry Model	1	First-Year Student	1	Motivation	1
E-Learning	4	Competency	1	Foreign Language Anxiety	1	On-line Teaching	1
STEM	3	Computational Thinking Skills	1	Foreign Language Learning	1	Performance	1
Collaborative Learning	2	Computer Aided Engineering Education	1	Health Course Module	1	Performance Assessment	1
Education	2	Computer-Supported Collaborative Learning	1	Initial Teachers Training	1	Problem Based Learning	1
Engineering Education	2	Constructionism	1	Interactive Learning Environments	1	Second Language Communication	1
Instructional Design	2	Continuing Professional Development	1	Language Education	1	Social Interaction	1
Academia Industrial Alliances	1	Creative Teaching	1	Learning	1	Student Engagement	1
Adult Learning	1	Digital Competence	1	Learning Environment	1	Teacher Education	1
Aircraft Maintenance Edu	1	Disabilities	1	Learning LMS	1	Teaching	1
Assistive Technology	1	Distance Research	1	Learning Methods	1	Teaching Practices	1
Autism	1	Educational Design Research	1	Learning Strategies	1	Teaching Technologies	1
Badging	1	Evaluation	1	Mathematics	1	Tertiary Education	1
Collaborative Work	1	Experiential Learning	1	Mobile Learning	1	Transformative Sustainability Edu.	1

The second category of keywords focuses on education-related terminologies (Table 5), where active learning (n=4) and e-learning (n=4) are the most common keywords of the dataset.

Table 6

Third Category of Keywords

Keyword	n	Keyword	n	Keyword	n	Keyword	n
Second Life	8	ARIMA	1	GEAR 5.0	1	Programming	1
Metaverse	4	Artificial Intelligence	1	Head-Mounted Display	1	Puppet Master	1
Open Sim	4	Avatar	1	Human Computer Interaction (HCI)	1	Quests	1
Augmented Reality	3	Blackboard	1	Immersive Technologies	1	Role Play	1
Massively Multiplayer Online Role - Playing Games (MMORPG)	3	Communication Technologies	1	Information Media	1	Scratch	1
Sloodle	3	Computer Software	1	Internet	1	Serious Games	1
Social Network	3	Computer-Mediated Communication	1	Metabot	1	Simulations	1
Game	2	Deep Learning	1	Mobile Agents	1	Speech Interaction	1
Mixed Reality	2	Distributed Information Systems	1	Mobile Technology	1	Video Games	1
Moodle	2	Educational Video Games	1	MS Teams	1	Web 2.0	1
Alternate Reality Games	1	Expert Systems	1	Playability	1	Zoom	1

Table 6 categorizes the keywords around technology, and ‘second life’ was the most frequent keyword of the dataset.

The researchers observed another category of library terms, which listed five keywords with a frequency of one: Library Orientation, Library Tour, Education Libraries, Public Libraries, and Information Services.

Table 7

Last Category of Keywords - 'Others'

Keyword	n	Keyword	n	Keyword	n	Keyword	n
Boeing 737	1	Epistemology	1	Nuclear Safety	1	Smart Maintenance	1
Change Management	1	Government	1	Ontology of Relationality	1	Smart Society	1
Children	1	Indigenous Philosophy	1	Pandemic	1	Social Justice	1
Concentration Power	1	Industry 4.0	1	Product Design	1	Spillover	1
Economics	1	Innovation	1	Regenerative Societies	1	Transformational Leadership	1
Employment	1	New Science	1	Relational Ethics	1	Youth	1

The fifth broad category was about research, and it includes the following keywords: Eye Blinking System, Eye Blinking Behaviors, Blinking Strength, Blinking Eyes, Biological Data, and Psychological Analysis (n=1).

Sampling was another research question of this paper. Although 27 of the articles did not mention the sample size clearly, the sample size of the remaining articles varies from 6 participants to 2000 participants. Additionally, three papers reported the following samples: one class of disabled students, three teachers and five companies. Lastly, only six articles overtly reported the sampling method as random sampling.

For addressing the fourth research question, we have found that 30 out of the 48 articles applied the metaverse at university level, two of them were in high schools and one was in secondary school. Fifteen articles did not mention explicitly the educational level of metaverse implementation.

In terms of the research method of the articles (the fifth research question), 56% of them were qualitative (n=27), 33% were quantitative (n=16) and 11% were mixed method (n=5).

Based on the researchers' thorough qualitative content analysis, seven major themes appeared in the selected papers (the sixth research question):

- The place of the metaverse in education in general,
- The possible implementations of the metaverse in different courses,

- The direct instructional support of the metaverse in education,
- The indirect instructional support of the metaverse in education,
- The variables/conditions of successful metaverse implementation in education,
- The possible challenges of metaverse in education,
- Encouraging research regarding metaverse in education.

After identifying the major themes, the researchers focused on the revealed categories and sub-categories.

Theme 1: The place of the metaverse in education deals with general instructional modes and activities. Collaborative learning (n=8), problem-based learning (n=4), active learning (n=3), e-learning (n=3), blended learning (n=2) and experiential learning (n=2) are the most frequent instructional modes associated with the utilization of metaverse in education. The following terms were also identified in the selected full texts:

- Appended social interaction
- Creative teaching
- Divergent thinking
- Learning to learn
- Remote teaching during pandemic
- Role play
- Social learning
- Tele-cooperation
- Telematic connection
- Transformative education

Theme 2: The researchers unfolded the possible metaverse implementations in different courses, which were listed either as applied in real life or suggested to be implemented. In general, it was reported that the metaverse can be utilized for a wide variety of educational purposes (n=1) and integrated into education at three different levels: course, program and university (n=1). Two additional papers specified that the metaverse could significantly contribute to university education and soon become an effective support for universities to benefit all types of distance learning systems.

Moreover, the metaverse was linked to STEM (science, technology, engineering and mathematics) education in three different articles. Certain articles also supported the similar point for each letter of STEM education; Science (n=1), Technology (with sub-categories of computer science (n=2), basic programming concepts (n=1)), Engineering (n=3) and Mathematics (n=3). Furthermore, one article discussed the use of the metaverse in medical education and another one dealt with about the metaverse as an alternative study choice for distance health students.

In another category, the metaverse was considered a useful platform to develop basic skills in communication. In addition, five articles stated that the metaverse is an effective language learning platform because of its visual (the positive effect of 3D over 2D (n=1)) and linguistic support for motivating students to engage in activities related to the learning of another language.

Lastly, the metaverse was associated with social science education, such as class activities in History, English (or any other native language) or literature-related courses. Furthermore, it was also pointed out that the metaverse can also be used in environmental sustainability, politics and international relations areas, where the participants can interact to share their knowledge and experiences on any of these topics.

Theme 3: The metaverse's direct instructional support was outlined by presenting the potential benefits it can offer based on the research findings. First and foremost, it was noted that the metaverse offers opportunities to look beyond the constraints of the traditional classroom environment (n=1). Furthermore, the metaverse was reported to increase interactivity in a course (n=4), to develop students' social skills (n=2), to increase student engagement and participation (n=1), and to provide a feeling of unity in the classroom (n=1) by creating group synergy (n=1).

It was also emphasized that students would feel comfortable (n=1) with a metaverse platform in addition to feeling less bored (n=1), more enjoyment (n=2) and decreasing their anxiety levels (n=1). Besides, students were happy that learning did not require physical attendance in a real classroom (n=1).

Reinforcement of education was another category identified in the study. In general, metaverse use reinforces subject content (n=1) and comes with a platform to assist students to reach their full potential (n=1). In a metaverse context, abstract concepts can be displayed visually to support knowledge (n=1), and the metaverse can reinforce students' higher order (n=1) and computational thinking (n=1) skills. For teachers, classroom notes can be enhanced with digital content on metaverse (n=1).

As an additional category, the metaverse was perceived as a support to social network knowledge construction (n=1), which can significantly favor student performance (n=1) and can lead to higher levels of achievement (n=1).

The last observed category was experimentation in education. Studies reported that the metaverse offers opportunities for remote collaboration of experiments (n=1) and that it is safer than making an experiment in real life (n=1). Moreover, the metaverse can decrease potential safety risks in real life situations (n=1) such as renewable energy (n=1) or radioactivity (n=1) experiments.

Theme 4: The indirect instructional support of the metaverse in education concentrates on moderating effects, such as cost effectiveness (n=1), as educational institutions do not need to buy expensive educational materials (n=3). Similarly, sharing content will be easier with the use of the metaverse (n=1) and with the help of digitally relocated resources (n=1). That will make the metaverse a solution to the geographical dispersion (n=3) of students, as the metaverse can save time and cut traveling expenses for cooperation among students and instructors (n=1).

The metaverse can go beyond education and can have positive effects at work (n=1). In other words, the metaverse can be a supportive tool for skilled workers and engineers (n=1) and it may be even used for preservice teacher training (n=1). Therefore, the metaverse has the potential to spur the development of learning and leadership in organizations (n=1). As a reflection of these points, the metaverse can establish a connection between students and libraries (n=1) and it can even create cooperation between universities and industry (n=1).

Lastly, the metaverse can assist students at disadvantage. For example, the metaverse can be an option for people with disabilities (n=2) or can decrease gender-based inequalities (n=1) in the educational context. Moreover, the metaverse can enhance students' social skills by allowing them more interaction with friends and even participating in music, sports, or any other extracurricular activities (including student clubs, and teams).

Theme 5: The variables/conditions of successful metaverse implementation in education comprise both instructional and technological factors to create an effective metaverse platform for instructional activities. One of the articles pointed out that metaverse in education combines all the variables of 'e-education, transformative learning, constructionism and cyberpsychology' (n=1) that needed to be carefully maintained to create successful applications. In another paper, it was claimed that a combination of collaborative learning, Web 2.0 applications and gaming would bring success to the metaverse in education. The instructional success variables/conditions mentioned in dataset are presented below:

- New learning scenarios (n=1), and distributed teaching scenarios (n=1) must be written to create nuanced learning experiences on the metaverse (n=1),
- Setting realistic expectations (n=1) and having clear sets of instructions (n=1) are important for metaverse instructional use,
- The metaverse should create a setting that is very alike to physical world to increase students' motivation (n=1),

- Metaverse requires gaming activities (n=1),
- Other than a fully metaverse-based education, the metaverse should be supported by offline activities (n=1), where the metaverse should be a supplementary environment (n=1) or an enhancement tool to classroom teaching (n=1).

The dataset contained a list of variables/conditions related to technological success, which were referenced.

- Other than enhancing game components only, the users' immersion in the Metaverse should be augmented (n=1). Therefore, full virtual world presence (n=3) providing higher sensation of immersion (n=1) must be guaranteed on a fully functional virtual architecture (n=1).
- Perceived usefulness of the metaverse is a significant variable (n=2). To serve that purpose, the quality of the metaverse interface (n=1) plays an important role. Additionally, avatars are as important as content (n=1).

In short, effective metaverse in education is possible with electronic interactivity, programming and the true instructional practice of temporal and structural electronic space (n=1).

Theme 6: Like many other technologies, the metaverse also comes with possible challenges for education. We are at the early stages of metaverse experiences (n=1), thus metaverse is like a new land for explorers (n=1) and educational stakeholders must discover possible challenges along with its benefits.

The major challenge was reported to be the high dependence of metaverse functionality on network infrastructure (n=2), which can be affected by slow internet connection (n=1) and can cause communication delay (n=1). The quality of animation and simulator (n=1) appears as another technological challenge for metaverse applications.

Evidently, the metaverse will raise technical issues (n=1), and it will need at least ten years to fully integrate into education (n=1). Moreover, perceptions regarding the technical difficulties of using the metaverse (n=1) can adversely affect its educational applications.

Time and cost challenges of developing metaverse platforms stay as an argument (n=3). However, open-source platforms can reduce the cost of metaverse platform development (n=3).

The world will see the effects of technological (n=3), cultural (n=3), socio-economic and political changes on the metaverse in the future. Challenges related to teaching in virtual space (n=2) and integration of user generated content into metaverse (n=1) will also be elaborated. Finally, it is forecasted that the metaverse will soon escalate potential legal issues (n=1).

Theme 7: The last theme concentrates on encouraging research regarding metaverse in education. As discussed above, the metaverse brings opportunities to students to engage with their peers in different languages. However, abilities in foreign languages might affect the interactivity. Therefore, one research paper employs a special algorithm to provide different language recognition and translation (experiment on Korean vs English) on the metaverse.

In two other research papers, blinking eye was taken into consideration as a variable. One of them showed that the number of the students' eye blinks increased with the difficulty of the problems so that teachers can evaluate the current attitude of their students. The other research concluded that when teachers were focused (having a high level of attention); they tended to blink more slowly and forcefully. Since the metaverse headsets / glasses are able to measure the number of eye blinks for a user, that data could provide certain information to instructors, including the difficulty of instructional materials or students' stress level.

Discussion

The Metaverse appeared in the academic debate on education in 2007, when three papers were published. The research in this field has maintained a consistent pattern of publication frequency (roughly a bit more than three papers per year, on average). Two crucial elements can be inferred from this observation. First, research is in its early-stage phase on such matters, and exemplifications, rather than clear-cut definitions, are provided to explain the concept. Second, although we may find examples of applications of the metaverse in education, the number of case studies is still quite limited, and they do not appear to cover all the types and levels of education.

As detailed earlier, the level of education most benefiting from the metaverse is higher education, while pre-university education case studies are almost non-existent (three papers about high school and secondary school). In addition, there are other levels of education that the metaverse could address, such as vocational, or those preparing various professionals. Apart from the formal education, the metaverse can prove beneficial for informal and non-formal education, where we have thus identified gaps in the literature – these types of education have not been addressed in research so far. We suggest that a selection of the successful examples presented in the pioneering

work that has been done so far could be grouped into a collection of good practice examples and guidelines.

We notice a poor representation of quantitative analyses on metaverse education, which is explained by the poor penetration of the technology in education as compared to its potential. Once the democratization of the metaverse in education is achieved in the future, it is to be expected that more quantitative studies be performed. From the selected papers, only one third employ a purely quantitative method. However, more applied analysis is required to quantify the outcomes of metaverse education, with representative samples.

A deeper look into the keyword categories reveals useful information as to the current state of knowledge about the Metaverse. The first category of the keywords in the 48 papers, i.e., virtualization, can help to identify synonyms or explanations for the Metaverse. The adjectives 'virtual' and '3D' are recurrent in explaining the Metaverse, and they are attached to nouns indicating the sphere, such as 'world', 'environment', 'reality', 'work', 'class', 'community'. Building on extant literature (Hill and Lee, 2009; Siyaev and Jo, 2021) and the synonyms above, we therefore suggest an enriched definition of the metaverse. *The metaverse is the virtual environment that enables interaction among participants, for various purposes such as education, communication, entertainment, work, by means of immersive (software and hardware) technologies under conditions of digital literacy, connectivity, accessibility, security, and sustainability.*

As described in the literature review section, one advantage of using the metaverse in education is breaking the geographical or cultural barriers in education (Ayiter, 2008), and implicitly mobility, which improves the outcomes of distance education (Irwin and Coutts, 2015; Lorenzo-Alvarez et al., 2019) and makes education more inclusive as it provides more opportunities (Abeles, 2007; Sidorko, 2009). Once the technology and infrastructure are in place, it can lead to a decrease in the education where certain experiments need to be carried out or materials used (Chau et al., 2013), but also to a decrease in travel expenses and time. Therefore, larger communities can be created for collaborative work and social interaction as additional outcomes within the educational process. However, digital literacy, technological endowment and connectivity are sine-qua-non-prerequisites to consider metaverse education a sustainable practice that would not further increase the digital divide (Oladokun and Aina, 2011).

In the field of formal initial education, the metaverse can be used for both activities attached thereto: learning (the student perspective) and teaching (the instructor perspective) (Dickey, 2010). Learning becomes active (Schiller, Goodrich, and Gupta,

2013) collaborative, experiential (Jarmon et al., 2009), blended, interactive and problem-based by means of technology. In the online environment, teaching practices can be more creative, with a focus on student engagement, motivation and performance, and student evaluation as part of the teaching process is no exception. The metaverse has been used for continuing education (i.e., adult learning, continuing professional development) as well as for the initial education and professional development of teachers. Nonetheless, the areas that have most benefited from the metaverse are STEM, health (Irwin and Coutts, 2015), language and communication. We suggest an extension of the metaverse application to other areas of study in social sciences and humanities, but also in library services (Hill and Lee, 2009), metaverse-education-related research and development and in special education.

In case metaverse technologies are used to enhance traditional education and improve its outcomes, we point out to the need for a balanced use of metaverse and traditional tools to preserve real communication and leisure time activities outside the virtual environment (Elsayed, 2020). In line with the conclusions of Zeide and Nissenbaum (2018), it is worth mentioning that the legal framework, especially in terms of data privacy and exposure, need to be updated to the emerging technologies. This is necessary to ensure safety and security while learning in immersive environments.

Since the rebranding of Facebook into 'Meta', the Metaverse has captured the attention of educational practitioners and researchers alike (Tlili *et al.,* 2022). This has been the turning point when the Metaverse started being considered a necessary complement (and sometimes an alternative) to traditional education. As such, future research needs to address up to what point immersive learning and teaching practices can bring benefits to students and what is the red line where shortcomings outweigh benefits (i.e., further inequalities such as digital divide, lack of privacy, exposure, use of private data beyond the scope of educational purposes, other ethical concerns, etc.), how to mitigate risks in the virtual learning environment, what the minimum physical infrastructure should be in order to use Metaverse in education on a larger scale, how to achieve better communication and interaction in the learning process by democratizing access to new technologies, how to use the Metaverse to increasing accessibility for students with special needs, how to raise awareness among the educational stakeholders on the need to prepare students for an increasingly virtualized (professional and personal) world, and how to better make use of virtual environments to functionally bring together educational establishments and the business sector when training future specialists in various fields. Last but not least, research should address the limitations of Metaverse in education and to what extent a substitution effect should occur between immersive and traditional teaching practices.

Conclusions

To the best of our knowledge, this study is the first systematic literature review on metaverse education. A research constraint could be related to the databases that have not been included in this study. Therefore, the present research can be extended by looking into the databases that have not been herein covered, but also later moment, by including research produced during the pandemic to capture metaverse developments under force online education settings (Siyaev and Jo, 2021). When the metaverse literature expands in the prospective years, the same systematic literature method should be applied to see the changes in the framework.

From research perspective, this study is important in the metaverse education landscape as it proposes a more comprehensive definition of the metaverse than the existing ones. In addition, the study identifies and proposes certain research directions that have not been addressed so far, such as: finding the right balance between the complementarity and substitutability of traditional and immersive learning/teaching practices and the associated risks and benefits of each for various fields of education and training; creating scalable teaching methods for a wider application of the Metaverse in education and accompanying them with the necessary and right technology. We have found that only small share of the total research employs quantitative methods, which is yet another research gap in metaverse education, mainly due to the fact that the research field is still in its infancy.

From a policy perspective, the proliferation of immersive teaching and learning methods raises the question whether this development further exacerbates the digital divide, inequities and inequalities among populations of students or regions. Therefore, policymakers will need ensure that students can benefit from equal opportunities, irrespective of their social, economic or ethnic background. This is quite a difficult task to achieve, especially because disparities had existed even before the recent explosion of the Metaverse in 2022. Adding to the previous digital divide may translate into different chances to access well-paid jobs, different insertion on the labor market, and eventually different standards of living in the long run. We recommend that educational, labor and technological endowment policies need to be aligned. Although special education centered on the needs of people with disabilities can be improved using the Metaverse, policymakers and educators should keep an eye on possible negative side effects it may generate.

From a practical standpoint, the research presents a collection of metaverse-education-related technologies (detailed in Table 6), which represent a repertoire for educators to consider when first adopting or enhancing their teaching portfolios and

methods. Furthermore, metaverse education can be the link between university and industry cooperation, as it can bring the two together in the educational process at lower costs. We recommend considering the use of immersive teaching environments for facilitating costly internships or for diminishing experiment-related risks in practical hands-on activities.

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Appendix 1 – References for Analyzed 48 Articles

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