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A systematic literature review of the acceptability of the use of Metaverse in education over 16 years

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Abstract
The use of Metaverse became popular to overcome the limitations of 2D e-learning. Metaverse has undergone significant changes in terms of application types, software, platform, and devices. Therefore, the emergence of the Metaverse influences users, especially students and teachers of different educational fields, in accepting or rejecting the use of the Metaverse. The PRISMA study aims to map the trends of changes in the use of Metaverse in education and examine its perceived usefulness and perceived ease of use from 2008 to 2022. The research findings are concluded as follows: (1) the trend of change from a single platform or software of the Metaverse to a more diverse combination of software and devices among the types of Metaverse in education; (2) the importance of perceived usefulness and perceived ease of use in the acceptance and rejection of the use of Metaverse in education. Future research suggests exploring the perceived usefulness and ease of use for a broader range of education fields, and considering different types in relation to the design of Metaverse platforms and devices.

Keywords Use of Metaverse · Perceived usefulness · Perceived ease of use · Education

Introduction

Metaverse has become a global trend due to the outbreak of the COVID-19 pandemic to overcome the spatio-temporal constraints faced by many domains. In October 2021, Mark Zuckerberg officially announced the rebranding and positioning of

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the Metaverse project as Meta. Horizon Workrooms is one of the innovations using the Oculus VR headset, which allows multiple people to meet in a virtual environment. The headsets are used for the spatial audio aspect, mainly to track the user's body movements, especially hands, and facial expressions to create an immersive experience (Hedrick et al., 2022). Thus, the announcement of the Metaverse project aimed to address the current disadvantages of 2D e-learning when educational institutions were heavily affected to meet the pandemic and social distancing measures. The disadvantages of 2D e-learning are inattention, inactivity, emotional isolation, and poor self-awareness. Many education sectors have begun to adapt and use Metaverse to overcome the limitations of online learning.

As the education sector begins to use Metaverse to overcome the limitations of online learning, it is necessary to examine user perceptions of the use of this technology in education. Therefore, stakeholders, such as policy makers and educational institutions, need to know whether teachers or students are willing to use Metaverse for their teaching and learning. In addition, perceived usefulness and perceived ease of use play a significant role in the use of Metaverse in education. It is necessary to investigate whether Metaverse is useful and easy to use for teachers and students. The results of the study are important for the future development of Metaverse.

Literature review

Metaverse

The concept of the metaverse existed 30 years ago when Neal Stephenson was the first to introduce it in his 1992 dystopian cyberpunk novel Snow Crash. The protagonist is described as existing virtually in a sentence on page 24 of the novel: "He is in a universe created by the computer. He can see with his glasses what the computer draws and hear what is pumped into his earphones. In technical jargon, this imaginary place is called a metaverse" (Stephenson, 2000). The "metaverse" then, is a virtual world composed of unique environments. Each of these environments serves a specific purpose, namely entertainment, socializing, and education. (Stephenson, 2000; Pimentel et al., 2022). Therefore, the word "Meta" in Greek means "beyond" and "verse" means the totality of something or the universe.

The emergence of a robust metaverse platform channel, such as Second Life and OpenSim in 2003, shapes the development of many Internet-related technological fields (Papagiannidls & Bourlakis, 2010; Jeon, 2021). Thus, Metaverse is primarily a 3D-based virtual world in which participants themselves can create an avatar (a configurable digital body) to interact with other avatars and digital objects in virtual space (Dhawan, 2020; Hrastinki, 2008, Mystakidis, 2022; Stöhr et al., 2020). In other words, Metaverse is an immersive 3D virtual world that allows users from all parts of the world to engage in social and economic interactions that are computational (Arcila, 2014; Díaz et al., 2020; Marquez, 2011; Vazquez-Cano & Sevillano-García, 2017; Akour et al., 2022). Therefore, the Metaverse was primarily developed as an immersive and interactive online game that allows users to experience social interaction in the virtual world. As a result, Second Life has been referred to as a precursor to the Metaverse (Dwivedi et al., 2022; Gent, 2022; Ludlow & Wallace, 2007). Meanwhile, current interactive 3D platforms such as Roblox, Minecraft, and Fortnite have become the model for the upcoming development of the Metaverse. Although these metaverse platforms have been around for more than two decades, the context of the metaverse is still limited by their platform independence and functionality (Dwivedi et al., 2022).

Since the outbreak of the COVID-19 pandemic, Metaverse has become a popular topic (Duan et al., 2021). It has become a new kind of Internet application and social form that integrates various kinds of new technologies (Ning et al., 2021). The metaverse has developed into a vast field by integrating advanced technologies, such as the collective space in virtuality (Lee et al., 2021), an omniverse combining the place of simulation and collaboration (Lee et al., 2021), the embodied Internet or spatial Internet (Chayka, 2021), the mirror world (Lee et al., 2021), the post-reality universe, a perpetual and persistent multi-user environment that merges physical reality with virtual reality (Mystakidis et al., 2022), and lifelogging (Bruun & Stentoft, 2019; Tlili et al., 2022).

Therefore, emerging technologies in the metaverse provide users with different experiences in teaching and learning. There are several examples of metaverse use in education. Metaverse was first introduced as a form of Virtual World (VW) when Second Life, a desktop virtual reality, was used as a platform in education. One study examined the advantages and disadvantages of VW to strengthen curriculum in an academic setting (Kluge & Riley, 2008; Manzoor, 2019; Suh & Ahn, 2022). Augmented reality (AR) technology during the COVID-19 outbreak can improve students' cognitive abilities related to knowledge retention and creativity. The use of metaverse technologies has been shown to promote autonomous learning (Lopes & Gonçalves, 2021; Suh & Ahn, 2022). In addition, a AR math game (van der Stappen et al., 2019) and a AR -supported storybook (Wangid et al., 2020) can help students reduce their math anxiety. The use of different types of metaverse in history teaching and their effects are of additional importance to teachers and education policymakers (Choi & Kim, 2017). Thus, it can be seen that most existing research on Metaverse applications in education focuses on VW and AR. The result is consistent with that of Hwang and Chien (2022) that the perspective of a strict definition of metaverse is still on VR or AR.

Although the use of Metaverse in education has changed significantly over the years in terms of the advancement of technology platforms and devices, the acceptance of users, i.e., teachers or students, in the use of Metaverse, especially in education, is still questionable. Therefore, it is important to determine whether the perceived usefulness and ease of use among teachers and students play an important role in the application of Metaverse in education. Therefore, the Technology Acceptance Model (TAM) is used for the study due to its simplicity and suitability for use in academic settings (Landry et al., 2006). The model contains three constructs: perceived usefulness, perceived ease of use, and intention to use. According to Shachak, et al. (2019), the simple nature of TAM makes it a useful tool that can directly measure user acceptance of new technologies compared to other models such as the Unified Theory of Acceptance and Use of Technology (UTAUT).

Technology acceptance model (TAM)

The Technology Acceptance Model (TAM) was proposed by Fred Davis in (1989) by adapting the psychological Theory of Reasoned Action (TRA) to create a reliable model that can help predict actual use of a technology (Davis, 1985; Granic & Marangunic, 2019). Therefore, TAM has become a key model for understanding the predictors of human behavior in relation to the potential acceptance or rejection of technology. There are three factors that TAM reveals can explain user behavior: perceived ease of use (PEOU), perceived usefulness (PU), and attitude toward use. The PU and PEOU can influence user attitudes (Davis, 1985, 1989).

TAM has been widely used for years to study the acceptance of learning technologies among students, teachers, and stakeholders (Davis, 2011; Granic & Marangunic, 2019). TAM is the most widely used foundational theory in the e-learning acceptance literature and has been explored for other learning technologies. For example, Sánchez Prieto, et al. (2016) studied TAM in mobile learning, del Barrio-García, et al. (2015) applied TAM to Personal Learning Environments (PLEs), Alharbi and Drew (2014) used TAM in Learning Management Systems (LMS), Sánchez and Hueros (2010) applied TAM to test the open source LMS Moodle, and Ibrahim, et al. (2017) investigated TAM for the commercial LMS Blackboard (Granic & Marangunic, 2019).

In addition, the theory of TAM has undergone some changes. The changes leading to the extended TAM or TAM2 have been updated not only by removing the attitudinal component from the model, but also by adding subjective norm, image, work relevance, output quality, and result demonstrability. The additional variables affect PU while the subjective norm affects both PU and behavioral intention to use (BI). The addition of the subjective norm in TAM2 serves to capture the social influence that affects end users' evaluation of whether to accept or reject the use of the technology (Holden & Karsh, 2010). To assess students' and teachers' acceptance or rejection of the use of metaverses in learning, PU and PEOU still play an important role. Therefore, TAM is chosen as the model in this study.

Perceived usefulness (PU)

Perceived usefulness (PU) refers to the extent to which individuals believe how useful the technology would be (Davis et al., 1989). PU is one of the self-efficacy perspective variables found in the model of technology acceptance (TAM) developed by Davis et al. (1989). PU has also been proposed as an influential antecedent shaping users' attitudes (Att) and behavioral intentions (BI) (Davis et al., 1989; Pavlou, 2003). TAM hypothesizes that PU influences the formation of positive attitudes related to the use of technology, which, when combined with PU, lead individuals to make better use of technology BI. Therefore, Davis (1989) emphasizes that PU plays a role in shaping users' attitudes toward technology use, and these attitudes influence users' behavioral intention to actual usage or reject the technology.

PU is the most important variable that influences the use or rejection of a new technology. Previous research has shown the impact of PU on teachers' and students' acceptance or rejection of a particular technology. Sprenger and Schwaninger (2021) conducted a study to test how PU students interact with four digital learning technologies. The study PU showed that mobile virtual reality had the lowest scores after three months of use. The reason for the low PU was too much time required to set up the mobile VR sequences, and some students were held up in class due to technical problems, which affected their PU for the technology. Luik and Taimalu (2021) found that PU was important to both teachers and students, which influenced their attitudes toward using technology in the classroom. The study also found that positive attitudes toward the use of technology is helpful for students and teachers, it might increase their positive attitude toward using technology in education. Scherer and Teo's (2019) meta-analysis of teachers' intentions to incorporate technology found that more than 80% of primary studies prove that PU influences behavioral intention (BI). So, this finding proves that PU works indirectly through Att to predict BI and indirectly. Thus, teachers' PU support teaching and learning processes that determine their intentions to use technology (Baydas & Goktas, 2017; Scherer & Teo, 2019).

Perceived ease of use

Perceived Ease of Use (PEOU) indicates how easy users believe the technology is to use. Like PU, PEOU is also part of the self-efficacy perspective variable. At the same time, PEOU has also been recommended as an influential antecedent condition that affects users' attitudes (Att) and behavioral intentions (BI) (Davis et al., 1989; Pavlou, 2003). PEOU plays the same role as PU in TAM, where PEOU influences the formation of positive attitudes related to technology use. Davis et al. (1989) also found that PEOU is likely to positively influence individuals' perceptions of the usefulness of technology (Ma et al., 2017). PEOU plays the same role as PU in influencing users' attitudes toward using technology by affecting users' behavioral intention to actually use or reject technology.

PEOU also plays the same role as PU as a critical variable influencing technology use or rejection. Research shows that PEOU is one of the critical antecedents of attitude and BI in adopting social media technology (Shin & Kim, 2008) and BI only in using cell phones (Tan et al., 2012). Some previous research shows the impact of PEOU on teachers' and students' use and rejection of technology. According to Moses et al. (2013), teachers are most likely to use a technology if it is easy to use and does not require effort to operate. Luik and Taimalu (2021) found in their research that PEOU has a significant favorable impact on both PU for teachers and students. However, PEOU was not confirmed to exert a significant influence on attitudes toward technology use when co-occurring with PU. The reason is that technology is used more frequently in education now than in the past, and when users can easily use technologies, PEOU has no influence on attitude. Therefore, PEOU must be combined with PU to influence attitude toward use. However, whether PEOU plays a significant role in the use of Metaverse in education is still debatable because not all students and teachers have used the devices or platforms in their teaching and learning.

Research questions

The use of the metaverse in education is proving popular, both during the COVID-19 pandemic and after Mark Zuckerberg announced the renaming and positioning of the Meta Project. However, research has examined the use of Metaverse in education not during or after the pandemic, but since 2008. They began with Shen and Eder (2008, 2009), who used TAM to investigate students' acceptance of using the Second Life VR platform in economics courses. Currently, Alfaisal et al. (2022) are conducting a systematic study on the use of metaverse systems in education. The study mainly focuses on eleven elements: (1) primary research objectives of the collected articles, (2) research methods, (3) primary countries, (4) primary disciplines, (5) educational levels, (6) primary software or tools, (7) research model used, (8) key factor categories, (9) commonly used research factors, (10) key database, and (11) trends over time. However, the study did not address the impact of metaverse trends on user adoption in education, which will be the outcome of the study. So, to what extent has the metaverse been integrated into education and how are users, i.e., students and teachers, responding? Therefore, it is crucial to investigate how the components of TAM: perceived usefulness and perceived ease of use, influence the acceptance of the use of Metaverse in education by students and teachers.

RQ1 What is the trend in the use of Metaverse in education? Between 2008 and 2022, what is the distribution of types of platforms, software, hardware, and devices based on the type of Metaverse in different education sectors?

RQ2 Does perceived usefulness in different education sectors play an important role in the use of different types of Metaverse?

RQ3 Does perceived ease of use in different education sectors play an important role in the use of different types of Metaverse?

Methods

In this study, the authors apply a systematic review, namely PRISMA (Preferred Reporting Items for Systematic reviews and Meta-Analyses). The authors apply PRISMA as the basis for reporting systematic reviews with objectives.

PRISMA

PRISMA is an accepted approach by Page et al. (2021), an evidence-based minimum set of items for reporting systematic reviews and meta-analyses. The authors searched three primary databases: Web of Science, Scopus, and Google Scholar. To answer research questions three and four, the following word sequences were used for the search: "metaverse" AND "educat*" OR "teach*" OR "learn*" OR "train*"AND "perceived usefulness" OR "perceived ease of use." The authors did not set a year limit, so the authors recovered all searches until November 14, 2022 to find out when the use of Metaverse in education started. Thus, the result of the search will provide information about the years when the use of Metaverse started and how long it has been used in education. The search was conducted to obtain the abstract, title, and keywords. Authors included only peer-reviewed articles and dissertations (Figs. 1, 2).

The word sequences were searched in the Web of Science (WoS), Scopus, and Google scholar databases. As a result, the authors identified three articles in Web of Science and 16 articles in Scopus and 621 articles in Google Scholar. According to Fig. 2, there were a total of 640 articles, 22 duplicate articles and 261 articles unrelated to Metaverse were removed, and 357 articles remained that were reviewed by title and abstract. The authors excluded articles if (1) the Metaverse was discussed in general terms and was not related to education; (2) Metaverse was applied in education but TAM was not applied; (3) the articles not written in English; (4) the articles were in the form of a review; and (5) the articles were not peer-reviewed articles or dissertations. Therefore, the authors included only 55 articles, while 302 others were excluded because they met all five criteria. The 55 articles were screened using the full text, and articles were excluded if

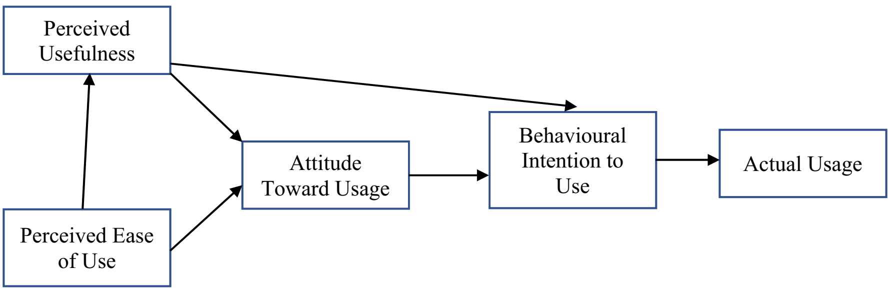


Fig. 1 The original technology acceptance model TAM (Davis, 1989; Tella & Olasina, 2014)

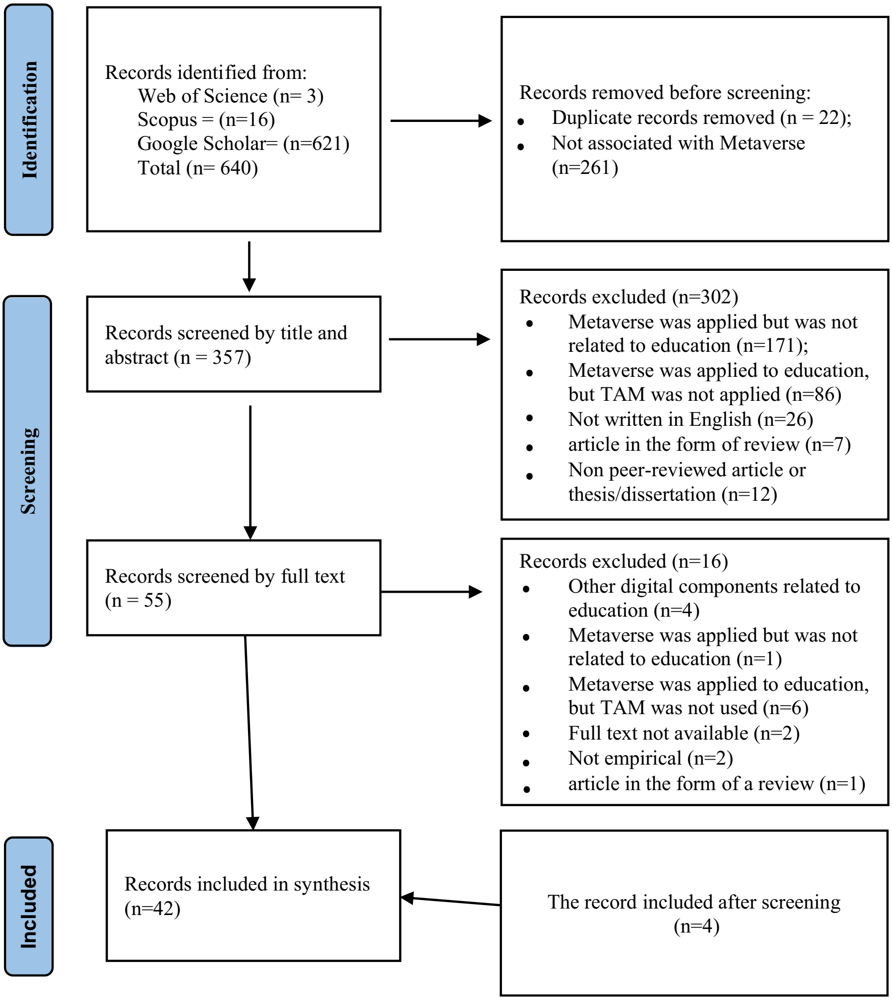
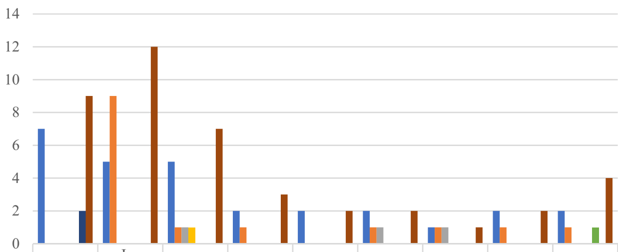


Fig. 2 Flowchart of study selection process

(1) other digital components related to education; (2) metaverse was applied but was not related to education; (3) metaverse was applied in education but TAM was not applied; (4) full text not available; (5) no empirical research; (6) article in the form of a review. Finally, only 39 articles were considered for synthesis. Four additional articles were extracted during the screening of full-text articles. During the selection process, two reviewers performed the literature filtering. If the two could not agree on a selection, a third rater was consulted to make a final decision. Inter-rater reliability reached a satisfactory level ($k = 0.77$).



	Medical / Healthcare	In-Service / Pre-service Teacher Training	Education (General)	Language	Business	Architecture	Engineer	Not mentioned	Other
Types of metaverse VR	7	5	5	2	2	2	1	2	2
Types of metaverse AR		9	1	1		1	1	1	1
Types of metaverse Mixed Reality /Extended Reality			1			1	1		
Types of metaverse Mirror Reality			1						
Types of metaverse AR	0								
Types of metaverse IoT	0								1
Types of metaverse Not mentioned	2								
Types of metaverse Total (Based on research article)	9	12	7	3	2	2	1	2	4

Fig. 3 Number of research based on education sectors and the type of Metaverse applied

Results

RQ1: What is the trend in the use of Metaverse in education? Between 2008 and 2022, what is the distribution of types of platforms, software, hardware, and devices based on the type of Metaverse in different education sectors?

According to Fig. 3, 42 articles were selected and analyzed as TAM was applied to them to investigate user acceptance based on the types of metaverse use in different educational fields. Educational domains include medicine and healthcare, teacher training and preparation, education in general, languages, business, architecture, engineering, and others not mentioned in the study. In medical or healthcare education, virtual reality (VR) is used most often, with seven research articles. In in-service and pre-service teacher education, on the other hand, augmented reality (AR) is used most frequently, with seven research articles, three articles involving only VR, and two articles involving both AR and VR. In general education, six of seven articles take place in higher education, four in applied education VR, and one each in IoT and AR. The only article that concerns elementary education uses both VR and reflection of reality in research. In language education, AR is used for English writing skills (Koç et al., 2022), VR for Chinese communication skills (Grant et al., 2014), and Spanish language (Lorenzo et al., 2013). Two business education courses include the use of VR (Shen & Eder, 2008, 2009). In architectural education, there are two articles, one of which uses VR, AR, and Mixed Reality (MR) (Cabero-Almenara et al., 2021), while the other uses only VR (Cantimur, 2009). There is one article from the field of engineering education that uses all VR, AR, and MR (Tümler et al., 2022). The others included four articles: Violence Prevention Education in

AI (Kang, et al., 2022), Automation Platform in VR (Shyr et al., 2022), Art History in AR and VR (Cabero-Almenara et al., 2022), and Fire Safety Education in Schools in VR (Mystakidis et al., 2022).

Table 1 shows that from 2008 to 2014, researchers began to investigate students' and teachers' perceptions of the acceptability of using Metaverse in education using TAM. The Second Life virtual reality platform is the platform that researchers have been using in various educational settings since 2008. Educational domains include medicine and healthcare, architecture, business, languages, teaching and learning in higher education, and teacher education and training. Faculty and students use a PC provided by the institutions or their personal computers. From 2008 to 2014, there has been almost one research per year in medical and health education, except in 2009 and 2012. Toro-Troconis is the one who has done the most research on the application of Second Life VR in medical and health education, followed by Vallance, et al. (2014). Meanwhile, Huang et al. (2013) use Virtual Body Structures-Auxiliary Teaching System (VBS-ATS) supported by desktop VR and projection VR in medical and health education. In business education, there is only one study per year, which VR used Second Life in 2008 and 2009. In language education, there was one study that used the VR application OpenSim in 2013 and one study in Second Life in 2014. In architecture education, there was only one research that used Second Life in 2009. In teacher education, there was only one study that used the AvayaLive Engage platform. There is also one study for Second Life in higher education, the other is not mentioned.

Researchers have begun to examine teacher and students acceptance by using TAM in the use of a wider variety of metaverses, not limited to Second Life virtual reality, between the years 2019 and 2022. Table 2 shows that researchers are beginning to use more than one VR or AR software to create activities in their teaching and learning. Girard (2021) presented several VR software: Spatial, Alcove, Notes on Blindness, Anne Frank's House, Gravity Lab, or Ecosphere for faculty in education to conduct hands-on activities with the Oculus Quest device. Meanwhile, researchers have begun to conduct research using marker-based AR tools: ARIS, Zapworks, Blippar Roar, and 3DQR to train teachers in training (Mikropoulos et al., 2022) and teachers in service (Koutromanos & Mikropoulos, 2021; Pasalidou & Fachantidis, 2021) in creating their AR application. Fung (2022) investigated how teachers in training integrate the platform VR called Minecraft into their foreign language teaching and learning. Two studies address teachers' perceptions of using different AR applications: WebART (Liu et al., 2022) and mobile AR computing platforms (Manna, 2022). Two types of research were conducted on both VR and AR, one related to teachers in training (Jang et al., 2021) and the other related to teachers in training (Cheng, 2021).

Different types of metaverses and platforms are used for language, architecture, and medicine. For example, Koç et al. (2022) investigated the use of AR Metaverse Studio in their study to help high school students create texts for their English writing skills. Cabero-Almenara, et al. (2021) use both VR and AR software to create a mixed reality environment for teaching architecture. The AR software was Zappar, Android Studio, Sketahfab, Autocard, Google sketah Up, and Adobe Photoshop; the VR software was Sketahfa, Google Sketachfa, Krpano and Google VR. Tümler et al.

Table 1 Types of Metaverse with platform, software, hardware, and devices apply across different education sectors between the year 2008 to 2014

Year			2008		2009		2010	2011	2012	2013			2014		
Education sector			M	B	A	B	M	M	GE	L	M	NM	M	PT	L
VR	P	SL	1	1	1	1	1	1	1			1	1		1
		OpenSim								1					
		Virtual Body Structures-Auxiliary Teaching System (VBS-ATS)									1				
		AvayaLive Engage												1	
		VirBELA (V-story)													
		Minecraft													
		CAVE-VR													
	S	Spatial, Alcove, Notes on Blindness, Anne Frank's House, Gravity Lab, or Ecosphere													
		Autodesk Maya software and Unity asset													
		Sketahfa, Krpano, Google Sketachfa, Adobe Google VR													
		Unity 3D, Fire Dynamics Simulator, and a script													
		Unity 3D, Krpano, Sketchfab, Adobe Photoshop													
	H	Roundshot VR robot in conjunction with a Canon EOS 6D camera													
	NM														
	D	PC	1	1	1	1	1	1	1			1	1	1	1
		Desktop VR & Projection VR									1				
		Oculus Quest													

Table 1 (continued)

Year			2008		2009		2010	2011	2012	2013			2014		
Education sector			M	B	A	B	M	M	GE	L	M	NM	M	PT	L
		low-cost VR headset													
		Cardboard VR													
AR	S	Metaverse studio													
		Zappar. Android Studio, Sketahfab, Autocard, Google sketah Up, Adobe Photoshop													
		ARIS, Zapworks, Blippar Roar, and 3DQR													
		WebART													
		Mobile Augmented Reality Computer Platform													
	NM														
	D	Android and IOS Smartphones													
		Google Glass													
		HoloLens 2													
IOT	NM														
AI	NM														
NM															

SL Second Life, *M* Medical/Healthcare, *B* Business, *A* Architecture, *GE* General Education, *L* Language, *E* Engineering, *PT* Pre-Service & In-Service Teacher Training, *SF* School Fire Preparedness Training, *HA* History of Art, *AP* Automation Platform, *P* Violence Prevention Education, *NM* Not mentioned, *P* Platform, *S* Software, *D* Device, *H* Hardware, *VR* Virtual Reality, *AR* Augmented Reality, *MiR* Miror Reality, *AI* Artificial Intelligence

Table 2 Types of Metaverse with platform, software, hardware, and devices apply across different education sectors between the year 2021 and 2022

Year			2019	2021					2022								
Education Sector			PT	PT	M	L	A	GE	E	M	GE	PT	SF	HA	AP	VP	NM
VR	P	SL															
		OpenSim															
		Virtual Body Structures-Auxiliary Teaching System (VBS-ATS)															
		AvayaLive Engage															
		VirBELA (V-story)									1						
		Minecraft										1					
		CAVE-VR											1				
	S	Spatial, Alcove, Notes on Blindness, Anne Frank's House, Gravity Lab or Ecosphere		1													
		Autodesk Maya software and Unity asset			1												
		Sketahfa, Krpano, Google Sketachfa, Adobe Google VR					1										
		Unity 3D, Fire Dynamics Simulator and a script											1				
		Unity 3D, Krpano, Sketchfab, Adobe Photoshop												1			
	H	Roundshot VR robot in conjunction with a Canon EOS 6D camera												1			
	NM									1	2				1		1
	D	PC							1								
		Desktop VR & Projection VR															

Table 2 (continued)

Year			2019	2021					2022								
Education Sector			PT	PT	M	L	A	GE	E	M	GE	PT	SF	HA	AP	VP	NM
		Oculus Quest		1	1				1								
		low-cost VR headset						1									
		Cardboard VR							1								
AR	S	Metaverse studio				1											
		Zappar. Android Studio, Sketahfab, Autocard, Google sketah Up, Adobe Photoshop					1										
		ARIS, Zapworks, Blippar Roar and 3DQR		1								1					
		WebART										1					
		Mobile Augmented Reality Computer Platform										1					
		Zappar. Android Studio, Sketchfab, Blender, GigaPan Stitch, Adobe Photoshop												1			
		Combination of the Vuforia SDK, Unity3D, 3D Studio Max, and image editing software	1														
	NM			2							1						1
	D	Android and IOS Smartphones				1			1								
		Google Glass									1						
		HoloLens 2							1								
IOT	NM										1						
AI	NM															1	

Table 2 (continued)

Year		2019	2021					2022								
Education Sector		PT	PT	M	L	A	GE	E	M	GE	PT	SF	HA	AP	VP	NM
MiR	NM									1						
NM									2							

SL Second Life, *M* Medical/Healthcare, *B* Business, *A* Architecture, *GE* General Education, *L* Language, *E* Engineering, *PT* Pre-Service & In-Service Teacher Training, *SF* School Fire Preparedness Training, *HA* History of Art, *AP* Automation Platform, *P* Violence Prevention Education, *NM* Not mentioned, *P* Platform, *S* Software, *D* Device, *H* Hardware, *VR* Virtual Reality, *AR* Augmented Reality, *MiR* Miror Reality, *AI* Artificial Intelligence

(2022) compared students' perceptions of using different AR and VR devices, such as PC-VR, Oculus Quest/Vive Focus, cardboard VR, HoloLens 2, and smartphone-based AR in engineering courses.

Table 2 shows how the acceptance of different types of metaverses, metaverses devices, and platforms by students in general education has been studied. There are two types of research that address the acceptance of higher education students' use of metaverse devices: low-cost headsets VR (Alamäki et al., 2021) and Google Glass (Aljanada et al., 2022). Almaiah et al. (2022) investigated university students' adoption of the Internet of Things (IoT) (Almaiah et al., 2022) and Kim et al. (2022) on the VR platform VirBELA (V-story). On the other hand, there are studies comparing elementary students' perceptions when using VR and Mirror Reality in learning (Suh & Ahn, 2022). However, there are two studies on VR and one study on AR, which do not specify the platform or device used in teaching and learning.

Table 2 illustrates that research on student perceptions of the acceptability of the use of metaverse in education has been extended to more specific teaching and learning methods, as well as to practical training. For example: fire safety in schools (Mystakidis et al., 2022), art history (Cabero-Almenara et al., 2022), automation platform with cyber-physical integration, and violence prevention education (Kang et al., 2022). The teaching and learning and hands-on training involve students at both higher and lower levels of education. Mystakidis, et al. (2022) designed, developed, and evaluated FSCHOOL, a serious game for fire preparation in an automated virtual cave environment (CAVE-VR) for elementary school teachers. They developed the game activities using Unity 3D with the help of the Fire Dynamics Simulator and a script to emulate and visualize fire spread. Cabero-Almenara et al. (2022) use a mixture of AR: Zappar. Android Studio, Sketchfab, Blender, GigaPan Stitch, and Adobe Photoshop, and VR software: Unity 3D, Krpano, Sketchfab, and Adobe Photoshop to create a mixed reality environment for art history classes. Shyr et al. (2022) used cyber-physical integration concepts to teach students in an automation platform. Kang et al. (2022) conducted a study to determine student awareness of using a chatbot (AuC), a type of artificial intelligence technology, to prevent violence among elementary school students.

RQ2: does perceived usefulness in different education sectors play an important role in the use of different types of Metaverse?

Perceived usefulness (PU) plays a critical role in technology integration in education. Research has demonstrated the role of PU in user acceptance of metaverse use in education. Table 3 shows that there are nine studies that address the acceptance of the use of Metaverse in the education of medical students and pre-service and in-service teachers. Seven studies address the use of Metaverse in the general education of students. Three studies deal with the use of Metaverse in language teaching, and two studies deal with the teaching and learning of business and architecture. In art history, mechanical engineering, fire safety education, automation platform, and school violence prevention, there is one study each on the use of Metaverse. Higher

Table 3 Details on application software, platform, and device used in Metaverse for education purposes

Medical											
No	Author	Field	Type of Metaverse					Devices/platform	PU	PEOU	Effects
			VR	AR	Mirror Reality	IoT	AI				
1	Toro-Troconis, et al. (2008)	Medical	/					Platform: Second Life	/		The VR group was more skeptical than the E-module group about didactic potential Both the VR and E-module groups felt that their learning experience was enhanced, justifying the extra effort Both the VR and E-module groups agreed that both applications offered more interesting and imaginative ways of learning The VR group emphasized that the learning experience with VR is less efficient and effective
2	Toro-Troconis & Mellstrm (2010)	Medical	/					Platform: Second Life	/		Women show a more positive overall attitude toward the perceived usefulness component than men do

Table 3 (continued)

Medical											
No	Author	Field	Type of Metaverse					Devices/platform	PU	PEOU	Effects
			VR	AR	Mirror Reality	IoT	AI				
3	Toro-Troconis (2011)	Medical	/					Platform: Second Life	/		The VR group was more skeptical than the E-module group about didactic potential Both the VR and E-module groups felt that their learning experience was enhanced, justifying the extra effort Both the VR and E-module groups agreed that both applications offered more interesting and imaginative ways of learning The VR group emphasized that the learning experience with VR is less efficient and effective
4	Huang, et al. (2013)	Medical	/					The Virtual Body Structures-Auxiliary Teaching System (VBS-ATS) (desktop VR and projection-based VR)	/	/	Immersion and imagination features of VR have a positive influence on PU and may also predict PEOU PU and PEOU contribute to students' use of BI VR learning systems

Table 3 (continued)

Medical

No	Author	Field	Type of Metaverse					Devices/platform	PU	PEOU	Effects
			VR	AR	Mirror Reality	IoT	AI				
5	Vallance, et al. (2014)	Medical	/					Platform: Second Life	/		Graphic/visual representations and simulations in VR had a positive meaning for students PU
6	Al-Hiyari (2021)	Medical/Healthcare	/					Device: VR Oculus Quest Software: Autodesk Maya software and Unity asset	/	/	First aid e-books had a higher PEOU than Virtual Aid PEOU predicts users' future intention to use Virtual Aid PU predicts student intent to use similar or other VR-supported training applications for learning and training
7	Almarzouqi, et al. (2022)	Medical	/					Not mentioned	/	/	Significant correlation between PU and PEOU Higher PU and PEOU lead to higher metaverse acceptance Students believe PU influences their intentions to adopt new technologies PEOU influences students' acceptance and adoption of the metaverse

Table 3 (continued)

Medical

No	Author	Field	Type of Metaverse					Devices/platform	PU	PEOU	Effects
			VR	AR	Mirror Reality	IoT	AI				
8	Alawadhi, et al. (2022)	Medical						Not mentioned	/	/	PEOU and PU influenced personal innovativeness (PI) PEOU and PU were statistically related to perceived pleasure (EJ) PEOU and PU significantly influenced students' propensity to use metaverse
9	Alfaisal, et al. (2022)	Medical						Not mentioned			PU and PEOU significantly influence users' intention to use metaverse

Pre-service and in-service teachers' perception

No	Author	Field	Type of Metaverse					Devices/platform	PU	PEOU	Effects
			VR	AR	Mirror Reality	IoT	AI				
1	Camilleri (2014)	Pre-Service Teacher Training	/					AvayaLive Engage			Students' PEOU and PU were not subject to significant change before and after the VR experience
2	Ibili, et al. (2019)	Primary school mathematics teachers		/				Augmented Reality Geometry Tutorial System (ARGTS)	/	/	PU was found to have a direct impact on attitudes (AT) Perceived Ease of use (PEU) had a direct effect on perceived usefulness (PU)

Table 3 (continued)

Pre-service and in-service teachers' perception											
No	Author	Field	Type of Metaverse					Devices/platform	PU	PEOU	Effects
			VR	AR	Mirror Reality	IoT	AI				
3	Girard (2021)	Pre-Service Language Teacher Training	/					Device: VR Oculus Quest 2 Software: Spatial, Alcove, Notes on Blindness, Anne Frank's House, Gravity Lab or Eco-sphere	/	/	Teachers examined the PU website from VR in the classroom Teachers focused more on PEOU in their professional development sessions
4	Cheng (2021)	Pre-Service Language (Teacher Training)	/	/						/	PEOU played an important role in helping student teachers select AR and VR applications or devices that were easy to use
5	Gómez-García, et al. (2021)	Primary Education Training		/				Not mentioned	/		No significant differences were found between the PU of students with AR and without AR

Table 3 (continued)

Pre-service and in-service teachers' perception											
No	Author	Field	Type of Metaverse					Devices/platform	PU	PEOU	Effects
			VR	AR	Mirror Reality	IoT	AI				
6	Jang, et al. (2021)	In-Service Teachers	/	/				Not mentioned			PU had an impact on ATU, mediated by PEOU PEOU addresses the value of and attitudes toward technology for teaching; newer technologies such as AR and VR may not yet be perceived by teachers as educationally useful PEOU and PU influenced ATU
7	Koutromanos and Mikropoulos (2021)	In-Service Teacher		/				A proposed Mobile Augmented Reality Acceptance Model called MARAM	/	/	PU is an important predictor of intention to use PU is an important predictor of attitude PEOU is not an important predictor of user intention to use and attitude
8	Pasalidou and Fachantidis (2021)	Primary School teachers		/				BlippAR app	/	/	PU and PEOU can influence the behavioral intention to use a new technology
9	Manna (2022)	Language Teachers' Perception		/				Mobile Augmented Reality (MAR) computer platform			PU and PEOU influenced teachers' attitudes toward the use of mobile augmented reality (MAR)

Table 3 (continued)

Pre-service and in-service teachers' perception

No	Author	Field	Type of Metaverse					Devices/platform	PU	PEOU	Effects
			VR	AR	Mirror Reality	IoT	AI				
10	Liu, et al. (2022)	Teachers' Perception		/				AR learning resource authoring tool: WebART	/	/	Teachers' PU did not significantly influence user experience of the AR authoring tool Teachers' PEOU had a positive and significant impact on their AR authoring tool user experience
11	Fung (2022)	Pre-service and In-service Teacher	/					Platform: Minecraft		/	Participants who have experience with PC games and video games have a higher PEOU than inexperienced participants
12	Mikropoulos, et al. (2022)	Pre-Service Teacher Training		/				Software: marker-based AR tool BlippAR	/	/	PU has a positive influence on the pre-service teachers' intention to use MAR PEOU did not prove to be a significant predictor of Att and PU. This is due to their perception of MAR as useful and enjoyable

Table 3 (continued)

General education

No	Author	Field	Type of Metaverse					Devices/platform	PU	PEOU	Effects
			VR	AR	Mirror Reality	IoT	AI				
1	Wimpenny, et al. (2012)	Higher Education	/					Platform: Second Life	/		Impact of PU in VR: how prepared were students and teachers to deal with usability hurdles when technology did not meet their expectations
2	Alamäki, et al. (2021)	Higher Education	/					Conventional video, 360 videos with or without the low-cost VR headset		/	Participants' poor initial experiences with the low-cost VR with more technical challenges and eye-strain (PEOU & PU) influenced user adoption of the low-cost VR
3	Akour, et al. (2022)	Higher Education	/					Not mentioned	/	/	PU was a significant predictor of the factor of users' intention to use the Metaverse system Student perceptions may be influenced by PEOU
4	Kim, et al. (2022)	Higher Education	/					VirBELA(V-story)	/	/	PU is a significant factor for intention to use PEOU negatively predicts intention to use

Table 3 (continued)

General education											
No	Author	Field	Type of Metaverse					Devices/platform	PU	PEOU	Effects
			VR	AR	Mirror Reality	IoT	AI				
5	Almaiah, et al. (2022)	Higher Education				/		Not mentioned	/	/	PU and PEOU have significant effects on IoT usage intention
6	Aljanada, et al. (2022)	Higher Education		/				Device: Google Glass	/	/	Google Glass adoption significantly correlates with PU and PEOU
7	Suh and Ahn (2022)	Elementary	/		/			Not mentioned	/		Students found Virtual World (VW) to be relatively fun, but not PU Students found Mirror World (MW) not fun, but had PU

Table 3 (continued)

Language

No	Author	Field	Type of Metaverse					Devices/ platform	PU	PEOU	Effects
			VR	AR	Mirror Reality	IoT	AI				
1	Lorenzo, et al. (2013)	Language	/					OpenSim			PU from VR platforms positively and directly influences the usage intent (BU) of the system for language purposes PEOU of VR platforms positively and directly influences behavioral intention to use the system for language purposes (BU) PEOU of VR platforms positively and directly influences PU of the system for language purposes
2	Grant, et al. (2014)	Chinese language						Platform: Second Life	/		Similarities to real-life situations can promote PU

Table 3 (continued)

Language											
No	Author	Field	Type of Metaverse					Devices/ platform	PU	PEOU	Effects
			VR	AR	Mirror Reality	IoT	AI				
3	Koç, et al. (2022)	Language (High School Students)		/				Software: Metaverse Studio Android and iOs	/		PU: Students perceived AR-based writing experience as useful to improve their writing skills PU: AR-based writing experiences facilitated students to organize their ideas during writing PU: AR-based writing experiences improved word choice and use of connectors in writing

Architecture											
No	Author	Field	Type of Metaverse					Devices/platform	PU	PEOU	Effects
			VR	AR	Mirror Reality	IoT	AI				
1	Cantimur (2009)	Interior Architecture Design	/					Platform: Second Life	/		Students PU showed that working with VR in the design course led to more creative and successful design

Table 3 (continued)

Architecture

No	Author	Field	Type of Metaverse					Devices/platform	PU	PEOU	Effects
			VR	AR	Mirror Reality	IoT	AI				
2	Cabero-Almenara, et al. (2021)	Architecture	/	/				Software: AR: Zappar. Android Studio, Sketahfab, Autocard, Google sketah Up, Adobe Photoshop; VR: Sketahfa, Krpano, Google Sketachfa, Google VR	/	/	Mixed reality (combination of VR and AR) significantly influences PU and PEOU

Business

No	Author	Field	Type of Metaverse					Devices/platform	PU	PEOU	Effects
			VR	AR	Mirror Reality	IoT	AI				
1	Shen and Eder (2008)	Business	/					Platform: Second Life	/	/	PU positively influence behavioral intention (BI) to use Second Life in education PEOU show no positive effect on BI to use Second Life in education PEOU positively influences PU of Second Life
2	Shen and Eder (2009)	Business	/								PU positively influences BI to use Second Life in education PEOU positively influences PU of Second Life

Table 3 (continued)

Other

No	Author	Field	Type of Metaverse					Devices/platform	PU	PEOU	Effects
			VR	AR	Mirror Reality	IoT	AI				
1	Schott (2013)	Workshop (Non-student participants)	/					Platform: Second Life			PU will positively impact behavioral intention (BI) to use VR for future collaboration in work groups PEOU will positively impact behavioral intention (BI) to use VR for future workgroup collaboration PEOU positively impacts PU to use of VR for future workgroup collaboration

Table 3 (continued)

Other

No	Author	Field	Type of Metaverse					Devices/platform	PU	PEOU	Effects
			VR	AR	Mirror Reality	IoT	AI				
2	Cabero-Almenara, et al. (2022)	History of Art Teaching	/	/				Hardware: Roundshot VR robot in conjunction with a Canon EOS 6D camera Software: AR: Zappar. Android Studio, Sketchfab, Blender, GigaPan Stitch, Adobe Photoshop; VR: Unity 3D, Krpano, Sketchfab, Adobe Photoshop Android, IOS	/	/	Students showed similar results to PU and PEOU in terms of using VR and AR

Table 3 (continued)

Other											
No	Author	Field	Type of Metaverse					Devices/platform	PU	PEOU	Effects
			VR	AR	Mirror Reality	IoT	AI				
3	Tümler, et al. (2022)	Mechanical Engineering	/	/				Devices: PC-VR, Oculus Quest/ Vive Focus, cardboard VR, HoloLens 2, smartphone-based AR	/	/	Students' PU and PEOU were different when collaborating across different xR device types. (PC-VR combined with Hole Lens 2 is the most appropriate multi-user setting)
4	Mystakidis, et al. (2022)	School Fire Preparedness Training (Elementary Students)	/					Platform: CAVE-VR Software: Unity 3D, Fire Dynamics Simulator, and a script	/	/	The effect of PU and PEOU on the VR training experience demonstrates the importance of developing an understanding of operations in order to use the proposed tool

Table 3 (continued)

Other

No	Author	Field	Type of Metaverse					Devices/platform	PU	PEOU	Effects
			VR	AR	Mirror Reality	IoT	AI				
5	Gim, et al. (2022)	-	/	/				Not mentioned	/	/	PU has a positive effect on perceived flow (PF) PU has a positive effect on learner satisfaction PEOU has a positive effect on perceived flow (PF) PEOU has a positive effect on learner satisfaction

Table 3 (continued)

Other

No	Author	Field	Type of Metaverse					Devices/platform	PU	PEOU	Effects
			VR	AR	Mirror Reality	IoT	AI				
6	Shyr, et al. (2022)	Automation platform: cyber-physical integration technique	/					Not mentioned	/	/	PEOU has a significant positive effect on attitude toward use; PEOU has a significant positive effect on perceived usefulness; PU has a significant positive effect on attitude toward use PU has a significantly positive effect on behavioral intention to use

Table 3 (continued)

Other											
No	Author	Field	Type of Metaverse					Devices/platform	PU	PEOU	Effects
			VR	AR	Mirror Reality	IoT	AI				
7	Kang, et al. (2022)	Violence Prevention Education (Elementary school student)					/	a chatbot (AuC)			PU is significantly positively correlated with intention to use an educational chatbot PEOU correlated significantly with intention to use

education has the most research, 38, two for elementary education and one each for secondary and non-student participants.

In medical and health education, four of nine research articles used the VR Second Life platform. The research was conducted between 2008 and 2014. The research results show that the graphics, visuals, and simulations in VR have a positive impact on students' PU (Vallance et al, 2014). However, Toro-Troconis, et al. (2008) and Toro-Troconis (2011) found that students in the VR group perceived the VR learning experience in medical education as less efficient and effective, which affected PU. On the other hand, Huang et al. (2013) applied the Virtual Body Structures-Auxiliary Teaching System (VBS-ATS) in desktop VR and projection-based VR and found that the immersion and imagination features of VR had a positive impact on PU. Meanwhile, Al-Hiyari (2021) used Autodesk Maya and Unity Asset software to create VR first aid. Students use VR Oculus Quest devices to learn first aid. It was found that the outcome of PU can predict students' intention to use similar or other VR-based training applications for learning and training. Although the research by Almarzouqi et al. (2022), Alawadhi, et al. (2022), and Alfaisal et al. (2022) did not specify the VR platform, software, and device usage, their results show that higher PU leads to higher metaverse adoption (Almarzouqi et al., 2022) and influences intention to adopt and use the technology (Alfaisal, et al., 2022; Almarzouqi et al., 2022). Alawadhi et al. (2022) found in their research that PU influences personal innovativeness (PI), is statistically related to perceived enjoyment (EJ), and significantly influences students' propensity to use Metaverse.

Pre-service and in-service teachers' perceptions of the acceptability of using metaverse in education play a critical role. There are eleven research articles on this topic, three of which address pre-service teachers' perceptions, seven of which address in-service teachers' perceptions, and one of which addresses pre-service and in-service teachers' perceptions. Camilleri (2014) used the VR platform AvayaLive Engage to examine how immersion in virtual environments can help change perceptions, enhance the experience, and overcome fears associated with the introduction of technology into the classroom. The study found that PU was not subject to significant change before and after the VR experience. The same result holds true for Gómez-García et al.'s (2021) study of elementary teacher education, which found no significant differences in students between using AR and without using AR. However, Mikropoulos et al. (2022) applied a group of marker-based AR tools: ARIS, Zapworks, Blippar Roar, and 3DQR to create Mobile AR (MAR), where PU positively influenced prospective teachers' intention to use MAR.

On the other hand, there are a total of seven studies on pre-service teachers' perceptions, five of which use AR, one of which uses VR, and one of which uses both AR and VR. Ibili et al. (2019) created an Augmented Reality Geometry Tutorial System (ARGTS) by using a combination of software such as Vuforia SDK, Unity3D, 3D Studio Max, and image editing software. They discovered that PU had a direct effect on attitude (Att), and PU was also a key predictor of satisfaction (SF). Koutromanos and Mikropoulos (2021) proposed a mobile augmented reality acceptance model to investigate teachers' perceptions. They found that PU is an important predictor of usage intention and attitude. The same results were obtained in

Pasalidou and Fachantidis' (2021) study when they introduced the BlippAR app to teachers. They found that PU had a positive impact on the intention to use AR apps in their classroom. The same is true for Manna (2022), who introduced a Mobile Augmented Reality (MAR) computing platform to teachers in training and found that PU influenced teachers' attitudes toward using MAR. Jang et al. (2021) investigated teachers' training in the applications of AR and VR and found that PU influences attention to technology use (ATU). In addition, PU is the mediated factor for the influence of PEOU on ATU. However, Liu et al. (2022) introduced the learning resource authoring tool AR: WebART and found that PU had no significant influence on the user experience of the AR authoring tool. Meanwhile, Girard (2021) trained in-service language teachers to use VR software such as Spatial, Alcove, Notes on Blindness, Anne Frank's House, Gravity Lab, or Ecosphere. At the same time, they were provided with a VR Oculus Quest device. The research found that teachers explored PU from VR in the virtual classroom.

In the area of general education, six studies concern higher education and one concerns elementary education. Four are about VR, each is about AR and IoT, and one is about both VR and mirror reality. Wimpenny et al. (2012) used the VR Second Life platform with college students. They found that the effect of PU was that students and faculty were willing to deal with usability hurdles when the technology did not meet their expectations. Alamäki et al. (2021) investigated students' perceptions of using conventional video and 360° video with and without a low-cost VR headset. The technical challenges and eye pain that would affect PU influenced the acceptance of the technology. Akour et al. (2022) and Kim, et al. (2022) also found PU to be a significant predictor of the metaverse system usage intention factor, with Kim, et al. (2022) using VirBELA (V-story). The same result holds true for Almaiah et al. (2022), who applied IoT to college students. Aljanada et al. (2022) also found that Google Glass use was significantly correlated with PU. However, Suh and Ahn (2022) investigated the use of VR and Mirror Reality (MR) with elementary students and found that students found VR to be entertaining, but it did not contribute to PU. Meanwhile, MR contributed to PU, but was not fun.

Table 3 shows three research papers on foreign language teaching and learning: Spanish (Lorenzo et al., 2013), Chinese (Grant et al., 2014), and English (Koç et al., 2022). Lorenzo et al. (2013) applied the OpenSim platform, a 3D learning environment that includes a combination of advanced communication tools (chat, video chat, or VoIP) and intelligent assistants (chatbots or NPCs). These communication tools and assistants play an important role in user adoption of using the Metaverse platform to learn a foreign language. Grant et al. (2014) investigated students' Foreign Language Anxiety (FLA) when VR Second Life was used to teach Chinese to beginners. Koç et al. (2022) use Metaverse Studio to create a AR experience to help students learn English writing skills. The study found that students found the AR-based writing experience useful in improving their writing skills, especially in helping them organize ideas while writing.

There are two research articles on business and architecture and one on engineering. Shen and Eder (2008, 2009) found that PU positively influences the behavioral intention (BI) to use Second Life in business education. Cantimur (2009), who also uses the Second Life platform VR to teach interior design, found that students'

PU showed that working with VR in design classes led to more creative and successful design. Cabero-Almenara et al. (2021) applied the combination of VR and AR, which is called mixed reality in architecture teaching. The AR software used to create them are Zappar. Android Studio, Sketahfab, Autocard, Google sketah Up, and Adobe Photoshop; VR is Sketahfa, Krpano, Google Sketachfa, and Google VR. Mixed reality was found to have a significant impact on PU. Tümler, et al. (2022) compared different VR and AR devices, such as PC-VR, Oculus Quest/Vive Focus, cardboard VR, HoloLens 2, and smartphone-based AR. The different devices had different effects on students' PU, and the combination of PC-VR and HoloLens 2 has the best multi-user setting.

There are six research papers that span a variety of educational domains that involve non-student participants in collaborative practise, school fire safety training, art history education, online learning, automation platform, and violence prevention education. Schott (2013) created a collaborative exercise in VR Second Life for non-student participants. He found that PU positively influenced behavioral intention (BI) to use VR for future collaboration in work groups. Mystakidis et al. (2022) used Unity 3D, Fire Dynamics Simulator, and a script to create a VR application for elementary school students to practise preparing for a school fire. It was found that the effect of PU in VR training experience is about the importance of developing an understanding of the operational procedures to use the proposed tool. Cabero-Almenara, et al. (2022) create AR and VR using the software AR: Zappar. Android Studio, Sketchfab, Blender, GigaPan Stitch, Adobe Photoshop; VR software: Unity 3D, Krpano, Sketchfab, Adobe Photoshop. The students of the study showed these applications related to object evaluation, which proved to be very reliable. Consequently, the students showed a positive result of PU over the use of VR and AR. Gim et al. (2022) used both AR and VR in online learning, where PU had a positive effect on perceived learning flow (PF) and learner satisfaction. Shyr et al. (2022) used VR in an automation platform: cyber-physical integration technology, with PU having a significant positive impact on attitude toward use and behavioral intention to use. Kang et al. (2022) used an AI chatbot (AuC) with elementary school students for violence prevention. They found that PU had a significant positive relationship with intention to use an educational chatbot.

Does perceived ease of use in different education sectors play an important role in the use of different types of Metaverse?

PEOU plays an essential role as PU in technology integration in education, and similar is true for the metaverse. Research has demonstrated PEOU's role in user acceptance of Metaverse use in education. Eleven studies focus on teachers, while five studies examine the acceptance of Metaverse use in education among medical and general education students. There are two studies in business education and one study each in art history, languages, architecture, mechanical engineering, fire safety education, and future workshop. Looking at the level of education, higher education is the most represented with 38 investigations, one investigation is in secondary education and non-student participation, and two are in elementary education.

Table 3 shows that in medical education, five research articles show that PEOU plays an important role in the use of Metaverse. Huang et al. (2013) used the Virtual Body Structures-Auxiliary Teaching System (VBS-ATS), a web-based interactive 3D learning system VR, designed for teaching undergraduate medical students human physiology, specifically the organs of the body. The researchers found that the immersive and imaginative features of VR had a positive impact on PEOU, which contributed to students' use of BI VR learning systems. Al-Hiyari (2021) compared first aid e-books and VR aid. The VR was created using Autodesk Maya software and Unity asset. The research found that first aid e-books have higher PEOU than Virtual Aid, and PEOU predicts users' future intention to use Virtual Aid. Although there are three studies on VR without specifying the software or platform used (Almarzouqi et al., 2022; Alawadhi et al., 2022; Alfaisal et al., 2022), PEOU was found to have a significant impact on users' intention to use Metaverse (Alawadhi et al., 2022; Alfaisal et al., 2022). Almarzouqi et al. (2022) found that PEOU influences students' acceptance and adoption of Metaverse, and that PEOU influences personal innovativeness (PI) and is statistically associated with perceived enjoyment (EJ) (Alawadhi et al., 2022).

Table 3 illustrates that there are six research papers on the training and perspectives of teachers in PEOU regarding the use of Metaverse in the classroom. There are five studies on AR applications and one on VR applications. Ibili, et al. (2019) used a combination of the Vuforia SDK, Unity3D, 3D Studio Max, and image editing software to create an Augmented Reality Geometry Tutorial System (ARGTS). The result shows that PEOU had a direct impact on PU and PEOU were an important predictor of satisfaction (SF). Pasalidou and Fachantidis (2021) introduced teachers in training to use the BlippAR app to design their own AR activities. Results showed that PEOU had a positive impact on teachers' behavioral intention to use AR apps in their classroom. Manna (2022) used the Mobile Augmented Reality computer platform (MAR) with teachers in education and found that PEOU influenced teachers' attitudes toward using Mobile Augmented Reality (MAR). Liu et al. (2022) used a AR learning resource provided by an authoring tool called WebART, where teachers' PEOU had a positive and significant impact on their AR user experience with the authoring tool. However, Koutromanos and Mikropoulos' (2021) study of AR applications among in-service teachers found that PEOU was not a significant predictor of user intention and attitude. Meanwhile, Girard, J. (2021) introduced teachers to the use of VR software, such as Spatial, Alcove, Notes on Blindness, Anne Frank's House, Gravity Lab, or Ecosphere with VR Oculus Quest 2 device. The research found that teachers tend to focus on PEOU in continuous professional development sessions.

On the other hand, there are three studies on the training and perception of pre-service teachers and one on the combination of pre-service and in-service teachers. Camilleri (2014) applied AvayaLive Engage and found that PEOU did not change significantly before and after the VR experience. Mikropoulos et al. (2022) introduced the use of the marker-based AR tool ARIS, Zapworks, Blippar Roar, and 3DQR to pre-service teachers to create AR applications for instruction. They found that PEOU was not a significant predictor of attitudes and PU. Only Cheng (2021) found that PEOU plays an important role in selecting AR and VR applications or devices that are easy for teachers to use.

For general education, there are five research papers on students' perceptions of their use of the metaverse in their general learning. Almaiah, et al. (2022) found that PEOU had a significant impact on intention to use the IoT. Aljanada, et al. (2022) found that Google Glass use was significantly correlated with PEOU. Akour, et al. (2022) found that PEOU can influence students' perceptions of using VR. However, Alamäki, et al. (2021) emphasized that students' poor initial experiences with the low-cost VR headsets, such as technical challenges and eye pain, influenced their PEOU, which in turn affected their acceptance of the device. Kim et al. (2022) also showed that PEOU negatively predicted students' intention to use VirBELA (V-Story).

There is one study on languages, architecture, and engineering and two studies on business that include PEOU in the acceptance of the use of Metaverse in teaching and student learning. Lorenzo et al. (2013) applied VR OpenSim in teaching Spanish as a foreign language. The PEOU of VR platforms positively and directly influences PU and behavioral intention to use (BU) the system for language purposes. Shen and Eder (2008, 2009) also found the same result as Lorenzo et al. (2013), but when using the platform VR Second Life. Cabero-Almenara et al. (2021), using both AR and VR software, found that mixed reality significantly affected PEOU. Tümler, et al. (2022) use various VR and AR devices, such as PC-VR, Oculus Quest/Vive Focus, cardboard VR, HoloLens 2 and smartphone-based AR in mechanical engineering. They discovered that students' PEOU were different when they interacted with different xR device types. For example, PC-VR combined with HoloLens 2 and smartphone-based AR in mechanical engineering. They found that students' PEOU differed when they interacted with different xR device types. For example, PC-VR combined with Hole Lens 2 is the most suitable combination for multi-user settings.

There are six research papers on PEOU among students in other educational settings, such as workgroup collaboration, school fire safety training, art history classes, automation platform, and violence prevention classes. Schott (2013) found that PEOU has a positive effect on behavioral intention (BI) and PU to use VR for future collaboration in work groups, especially in the Second Life platform VR. Mystakidis et al (2022) created school fire preparedness training using VR software such as Unity 3D, Fire Dynamics Simulator, and a script that students can access through CAVE-VR. The research results on the impact of PEOU in VR facilitated the students' understanding of the importance of understanding the operational procedures to use the proposed tool. Cabero-Almenara et al. (2022) used both AR and VR using hardware, e.g., a Roundshot robot VR in conjunction with a Canon EOS 6D camera. Using AR and VR has the same result for PEOU. Gim et al. (2022) used both VR and AR in online learning, where PEOU had a positive effect on perceived learning fluency (PF) and learner satisfaction. Shyr, et al. (2022) applied an automation platform: cyber-physical integration technology, where PEOU had a significant positive effect on attitudes toward using PU. Kang et al. (2022) is the only study using AR chatbot (AuC) for elementary students in violence prevention. They found that PEOU was significantly correlated with intention to use.

Discussion

Trends in platform, software, hardware, and device types based on the nature of the metaverse in various education sectors between 2008 and 2022. From the overall review, it appears that between 2008 and 2014, more research was conducted on the use of TAM to assess student acceptance of the use of metaverse (VR), specifically the Second Life platform, compared to other types of metaverse. The use of Second Life is limited only to the use of the personal computer provided by the institution's computer lab or students themselves. In 2019 to 2022, the use of Metaverse in education will be widespread and will not be limited to VR but also to AR, AI, and IoT. The number of Metaverse users jumped between the years 2021 and 2022, with a wider variety of software being used to create AR and VR applications for teachers and for students to use in learning. This situation may be caused by certain reasons. (1) more affordable prices for AR and VR devices with rapid technological advances; (2) the ongoing Covid 19 pandemic, which brings an increasing demand for non-face-to-face services, including teaching and learning; (3) more digital natives among teachers and students; (4) the ubiquity of mobile devices and changes in content types have given users the ability to access Metaverse anytime, anywhere (Suh & Ahn, 2022).

The important role of perceived usefulness in the use of metaverse in education

Perceived usefulness (PU) plays a critical role in influencing teachers' and students' use or rejection of new technologies, including the use of Metaverse in education. Davis (1986) clarifies that PU refers to the extent to which a person believes that the use of technology would improve his or her attitude toward technology. PU plays a vital role in influencing teachers' perceptions of accepting or rejecting the use of Metaverse in their teaching. In teacher education, PU was not found to significantly change VR experiences (Camilleri, 2014), with and without the use of AR (Gómez-García et al., 2021). However, Mikropoulos et al. (2022) showed that PU had a positive impact on prospective teachers' intention to use MAR. Camilleri (2014) explained that the incomplete technological infrastructure of the institution prevented faculty from using VR for instruction and that PU had not significantly changed their experience with VR. The findings of Gómez-García et al. (2021) are due to the fact that the attractiveness of AR promotes the learning of prospective teachers or future students rather than its future applicability in the classroom. However, Mikropoulos et al. (2022) found that pre-service teachers viewed PU positively from MAR not because it is easy to use, but because they believe it has some advantage over other digital technologies and is fun to use. Therefore, PU plays an important role in predicting prospective teachers' intention to use it rather than whether it is an appropriate requirement for use in their school (Mikropoulos et al., 2022).

PU In-service teacher training found that the introduction of AR software for teachers to create AR applications for teaching and learning had a significant impact on intention to use (Koutromanos & Mikropoulos, 2021; Manna, 2022; Pasalidou & Fachantidis, 2021). The uses of AR include the BlippAR app in teaching about the

Earth and the Moon (Pasalidou & Fachantidis, 2021), the MAR computer platform (Metaverse) in teaching Italian (Manna, 2022), and MAR (Koutromanos & Mikropoulos, 2021). Huang et al. (2016) confirmed that teachers consider MAR as a useful educational application if they believe that the application can increase their teaching effectiveness. AR Software also shows that PU has a positive effect on attitude. For example, Ibili et al. (2019) shared the Augmented Reality Geometry Tutorial System (ARGTS) with teachers and discovered that teachers' attitudes toward using the system increased positively when their perceptions regarding the usefulness of ARTS increased in the same way. Jang et al. (2021) found in the use of AR and VR that PU has a positive influence on attention to use, as teachers with knowledge of VR and AR are more concerned about the usefulness of the applications in teaching and learning. However, Liu et al. (2022) found that PU did not have a significant influence on teachers' experiences with the learning resources authoring tool AR. This is because most teachers already had a high level of PU in using ICT tools in their daily lives. Therefore, the variable PU did not have a significant impact on teachers' experiences with the AR authoring tool.

A similar result is also found in students PU, where PU is a significant predictor of the Metaverse usage intention factor (Shen & Eder, 2008, 2009; Schott, 2013; Lorenzo et al., 2013, Akour et al., 2022, Almarzouqi et al., 2022; Kim et al., 2022, Alfaisal et al.,2022; Almaiah et al., 2022, 2022, Shyr et al., 2022; Kang et al., 2022). Metaverse uses include VR (Akour et al., 2022; Almarzouqi et al., 2022), VirBELA (V-story), a VR platform (Kim et al., 2022), VR Second Life platform (Schott, 2013; Shen & Eder, 2008, 2009), VR OpenSim platform (Lorenzo et al., 2013), and IoT (Almaiah et al., 2022). However, Alamäki, et al. (2021), who used inexpensive headsets, found that students had low PU due to technical issues and eye pain when using the device. In addition, Wimpenny et al. (2012) used the platform VR Second Life, which showed that students' PU was low when their use of the technology did not meet their expectations.

The result of this research can be underlined by Scherer and Teo (2019) that PU influences students' intention to use new technologies such as Metaverse. For students of the younger generation, especially Generation Z, the uniqueness influences them that motivates them to adopt technological innovations (Lai, 2017; Liu et al., 2009). Padilla-Meléndez and Garrido-Moreno (2013), Lin and Yeh (2019), and Wang et al. (2021) also explain that the level of PU among students may vary depending on technological innovation features such as Google Glass (Aljanada et al., 2022) and uncertainty level. Therefore, if the use of metaverse can improve their learning, students are more likely to accept the use of metaverse in education. However, if the use of Metaverse cannot enhance their learning, such as technical challenges and eye pain due to the low-cost VR (Alamäki et al., 2021) and hurdles in usability if the VR Second Life platform does not meet their expectations (Wimpenny et al., 2012). These reasons will lead students to not accept the use of Metaverse in education. The technical problems of Metaverse and the time required to set up the Metaverse platform may be the reasons that lead to low PU among students.

In addition, different types of metaverse have different effects on students PU, especially in medicine. Toro-Trononis (2008) and (2011), and Vallance et al. (2014)

used the VR Second Life platform to create virtual patients for medical students. Although graphics, visuals, and simulations in VR have a positive impact on students' PU, students stated that they find interaction with virtual patients are incompetent. This is because they are familiar with working on cadavers and expect a natural and intuitive interaction experience. They will only occasionally access virtual patients to learn clinical assessments. The same findings were also found by Vallance et al. (2014) that the use of Second Life in clinical assessment of child and adolescent psychiatry only serves as a supplement and not as a substitute for the real situation. Therefore, the clinical assessment of VR can only add value to distance learning. However, Huang et al. (2013) came to a different research conclusion. They use the Virtual Body Structures-Auxiliary Teaching System (VBS-ATS) to create a 3D simulation world that facilitates students to learn body organs effectively. Thus, the immersion function of the VR technology creates a 3D simulation world that helps learning. Huang et al. (2013) further explained that the design of a VR learning environment provides a reduced level of interactivity. The system mainly provides interaction functions, such as rotating and zooming in/out organ models, to help students learn body organs.

Besides that, different types of Metaverse and the devices used also have different effects on PU. Suh and Ahn (2022) state that different types of metaverse have different effects on PU. For example, the virtual world (VW) makes students feel that using the platform is fun, but it creates a low PU because it does not make students feel useful. Students perceived VW as fun because they were exposed to VW as a form of entertainment with games such as Roblox and Minecraft, which made them perceive VW as fun. Camilleri (2014) believes that VR is not perceived as useful because many technological infrastructures of educational institutions do not support the requirements for using VW for teaching and learning purposes. In contrast, Mirror World provides students with a high PU, as it creates a perceived usefulness but fails to provide students with a sense of enjoyment. Students perceive MR as functional due to the complementary social distancing during the COVID-19 pandemic, with MW being the central core for online learning. Thus, the use of MW leads students to perceive MW as valuable to their learning, but not fun. Furthermore, Tümler et al. (2022) found that PU differs when working with different xR device types, with a combination of PC-VR and Hole Lens 2 being best suited for use in multi-user environments. Therefore, different metaverse devices impact student learning at PU. Therefore, PU plays an important role in the use of different types of metaverse in education.

Important role of perceived ease of use in the use of Metaverse in education

Perceived ease of use plays an important role in the use of Metaverse in education because it influences teachers' and students' use or rejection of the technology. Davis (1986) describes PEOU as the extent to which a person believes that using the technology is effortless or easy. PEOU plays a critical role in teachers' perceptions of accepting or rejecting the use of metaverses in the classroom. According to Liu et al. (2022), the higher the PEOU score, the less effort teachers need to put into using technology at work. At the same time, teachers who perceive technology as easy to use are likely to have better experiences with new technology-related environments such as Metaverse. However, Mikropoulos et al. (2022) and Koutromanos and Mikropoulos (2021) disagree with this point. In their studies, PEOU was found not to correlate with PU and Att, which can be attributed to the presence of perceived enjoyment. In other words, teachers have positive or high levels of PU not because Metaverse applications are easy to use, but because they perceive them as more enjoyable (Koutromanos & Mikropoulos, 2021).

Most researchers found that students' perception of PEOU influences their acceptance or rejection of technology integration such as Metaverse (Shen & Eder, 2008, 2009; Schott, 2013; Lorenzo et al., 2013, Shyr et al., 2022). Therefore, according to Taylor and Todd (1995) and Venkatesh and Morris (2000), it is therefore explained that PEOU is positively associated with PU, suggesting that students readily adopt new technological innovations when they are familiar with the technology and believe that its use requires less effort. Davis (1985) emphasized that PEOU is viewed as the degree of effectiveness and comfort students experience after using an innovative technology such as the Metaverse. For example, Mystakidis et al. (2022) created a fire safety course for schools using VR software such as Unity 3D, Fire Dynamics Simulator, and a script that students can access through CAVE-VR. They discovered the impact of PEOU in VR training experience facilitates students on the importance of understanding the operational procedures to use the proposed tool. Thus, if students feel that using Metaverse in their learning process is easy and the technology facilitates their learning, they will be more likely to accept the use of the technology in their learning process.

Different types of Metaverse in the form of platforms and devices with different characteristics tend to affect teachers' and students' PEOU. Thus, if the devices and platforms of the Metaverse are easy to use by teachers and students, teachers and students are likely to accept the use of devices or platforms (Lorenzo et al., 2013; Schott, 2013; Cheng, 2021, Kang et al., 2022; Akour et al., 2022; Almaiah et al., 2022). However, in the study by Kim et al. (2022), PEOU was found to negatively predict intention to use the VirBELA (V-story) platform. This result is due to the multiple functions of the Metaverse, such as movement instructions, verbal communication, text-based communication, and non-verbal communication such as gestures, which increase students' cognitive load when using the Metaverse. This causes students to be fearful of the technology, which negatively affects their intention to use it (Kim et al., 2022). In addition, the device quality of the Metaverse has another influence on PEOU. For example, in the study by Alamäki et al. (2021), conventional videos were compared with, with and without a low-cost VR headset. The study found that technical problems and eye pain were the main factors that affected students' PEOU when they used the device for learning. In addition, the different devices of the Metaverse, such as VR and AR, have different effects on PEOU during learning. For example, Tümler et al. (2022) found that PC-VR and HoloLens 2 were more likely to be used by students than other device combinations due to ease of access.

Conclusion

The use of the metaverse in education was intended to replace the limitations of 2D e-learning during the pandemic outbreak COVID-19. At the same time, it was also the influence of Mark Zuckerberg who officially announced the renaming and positioning of the Metaverse project with the name Meta. As a result, the use of Metaverse in education increased dramatically in 2022. Although the number of research papers on the use of Metaverse in education jumped in 2022, the integration of Metaverse in education was introduced in 2008. Therefore, the conclusion of the study relates to (1) the trend of change in Metaverse in education; (2) the importance of perceived usefulness and perceived ease of use in the acceptance and rejection of the use of Metaverse in education; and (3) the recommendations for future research.

The trend changes from a single platform or software of the Metaverse to a more diverse combination of software and devices in types of Metaverse in education. The integration of Metaverse in education began in 2008 with the application of the virtual reality Second Life as the main platform among researchers in various educational fields. At that time, TAM was used to study the acceptance of users, mostly students, to use the platform. However, other types of metaverse have been introduced in the educational field, involving not only students but also teachers in pre-service and in-service teachers. The types of metaverse are not limited to the use of virtual reality, but also to mixing with augmented reality to form mixed reality, or using either type of metaverse. The results are consistent with Hwang and Chien's (2022) definition that most existing applications of metaverse are AR or VR. However, the types of Metaverse that leverage AI and IoT have now emerged. The cost of the software used to create applications AR or VR is passed from teachers to students, and a variety of platforms and devices are used to facilitate teacher and student teaching and learning.

The metaverse is undergoing a trend of change and is being updated in terms of software, platforms, devices, and types of metaverse. Therefore, the perceived usefulness and perceived ease of use of TAM play a critical role in teachers' and students' acceptance or rejection of different types of Metaverse. Therefore, whether Metaverse is easy to use for learning or enhances learning is critical for learners to decide whether to use or reject the technology. The same condition applies to teachers: if using Metaverse is easy to access and helpful for teaching, teachers are more likely to use the technology.

The current study only examined perceived usefulness and ease of use in educational settings that span many domains. However, the research mainly focuses on the fields of medicine, teachers in training and development, and higher education, while little research has been conducted in the other educational fields. For future studies, it is recommended to (1) Include a broader range of educational domains. A broader range of educational sectors that use Metaverse should be studied in terms of how perceived usefulness and perceived ease of use influence users' intentions to use. (2) The design of the Metaverse platform and devices. Since the Metaverse platforms and devices also influence perceived usefulness and perceived ease of use among their users, this should be further investigated. These results can inform how Metaverse platforms and devices can be designed in different educational settings. They will make it easier for students and teachers to use Metaverse in education.

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Data availability We make sure that all data and materials support our published claims and comply with field standards.

Declarations

Conflict of interest We have no conflicts of interest to declare that are relevant to the content of this article.

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