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Broad sense and narrow sense perspectives on the metaverse in education: Roles of virtual reality, augmented reality, artificial intelligence and pedagogical theories

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Abstract: There are different definitions of the metaverse. Some are from technical perspectives, which emphasize multiple criteria for identifying a metaverse system, such as being persistent, shared, and decentralized. On the other hand, some researchers consider metaverse as a virtual learning environment which enables people to interact with others or experience authentic contexts. Owing to the diverse notations of the metaverse, educational researchers might feel confused and wonder how the metaverse can be used in educational settings and whether the systems they have used can be called the metaverse. In this paper, we address this issue from different angles, the broad sense and the narrow sense. In particular, the broad sense definition is proposed from the perspective of educational objectives and needs. Moreover, research design modes regarding the metaverse in education are discussed by considering the roles played by emerging technologies, such as virtual reality, artificial intelligence, and mobile technologies.

Keywords: metaverse; emerging technologies; virtual learning; augmented reality; artificial intelligence

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1 Overview of the metaverse

The "metaverse" is a term for describing a shared, immersive and interactive virtual world where people have a sense of presence and interact with each other and with virtual objects and environments (Sun et al., 2022). In the last decade, the term "metaverse" has attracted attention from researchers around the globe. Many scholars have considered that the metaverse is the next generation of social medium, in which a world can be created to enable people to experience the virtual contexts and interact with people and objects in the world following the regulations specified by the creators (Chen, 2022). From a user interface perspective, a user of the metaverse could be situated in a completely virtual world like a virtual reality (VR) environment; alternatively, the metaverse could be a partially virtual world, such as situating users in real-world contexts with augmented reality (AR) content (Lee, 2022; Zhang et al., 2022). The former (i.e., the fully virtual world) is a more frequently adopted form of the metaverse, while the latter has been adopted by several game companies (Faqih, 2022). In each form of the metaverse, users can live in a virtual world with real people and NPCs (non-person characters); they can have new identities, a virtual family, new jobs, new bank accounts, and social activities (Oh et al., 2023; Zhang et al., 2022). It is something like the users being in a parallel world to their real lives (Lee, 2022; Zhang et al., 2022). In this new world, everything that happens in the real world could occur; more importantly, many ideas that people believe to be impossible could come true; for example, people might be able to fly, and technologies could be at a totally different level, depending on the imagination of the creator (Lee, 2022).

2 Narrow-sense definition

From a narrow-sense perspective, Zhang et al. (2022) have defined the metaverse as a virtual world created using advanced technologies, and is much more than merely a virtual environment, online community or interactive contexts supported by AR or VR. Figure 1 depicts the framework presenting a narrow-sense metaverse, which consists of three features, making it different from conventional virtual environments (Cao, 2022; Tang et al., 2022), that is, it is "shared," "persistent," and "de-centralized." Huynh-The et al. (2023) further indicated that artificial intelligence (AI) plays the crucial role of enabling a metaverse to work based on the regulations set by its creator. According to the narrow-sense definition, AR and VR are the components of a metaverse that present the virtual content, while AI is the component for determining when, where and how to present the content. Moreover, the metaverse needs to be a multi-user system to fulfil the "shared" feature; it also needs to be a system that is executed persistently to meet the "persistent" feature. In addition, it should employ some decentralized technologies, such as blockchains, to prevent the data and logs of the metaverse from being modified or destroyed so as to meet the "de-centralized" feature (Zhang et al., 2022). As these criteria heavily depend on high levels of technology, most educational technology researchers could hesitate to conduct studies of the metaverse in education owing to the technical barriers.

Based on this narrow-sense definition, new metaverse applications as well as wearable devices have been developed by several companies (Egliston & Carter, 2022; Lee, 2022;

Ren et al., 2022). For example, Meta Platforms developed Oculus, a head-mounted display device, to enable people to interact in the metaverse (Egliston & Carter, 2022). For most people, the most impressive application of the metaverse could be in the form of an immersive computer game (Chen, 2022; Ren et al., 2022). On the other hand, the technical barriers and economic considerations of the narrow-sense metaverse could prevent researchers with a non-technical background from adopting it, in particular in the field of education or educational technology. From an ideal narrow-sense perspective, a metaverse is not only a multiuser environment, but also enables users to continuously explore in the environment; moreover, the environment needs to guarantee everything gained by the users (e.g., their credits and properties) as well as securing their logs in the virtual world (Dwivedi et al., 2022). Additionally, AI technologies play a crucial role in the narrow-sense metaverse. It needs to ensure the simulated world functions based on the rules defined by its creator. In such a multi-user and persistent virtual world, "Arbitration" could be required when there are conflicts or competitions among people, in particular, in metaverse-based games. One of the representative platforms of the narrow-sense metaverse is Roblox, developed by Roblox Corporation. Roblox is a gaming platform on which users can design and play their own games, as well as games created by other users. The platform also has social features such as chatting, messaging, and the functions of joining groups and creating friend lists. From the perspective of education, Roblox can be used for educational purposes in a variety of ways. For example, Roblox provides a platform for students to learn how to design and code their own games and interactive experiences. This can help them learn programming and game development skills in a fun and engaging way. It offers students an opportunity to develop skills that will be increasingly important in the future, such as coding, digital literacy, and collaboration in virtual environments.

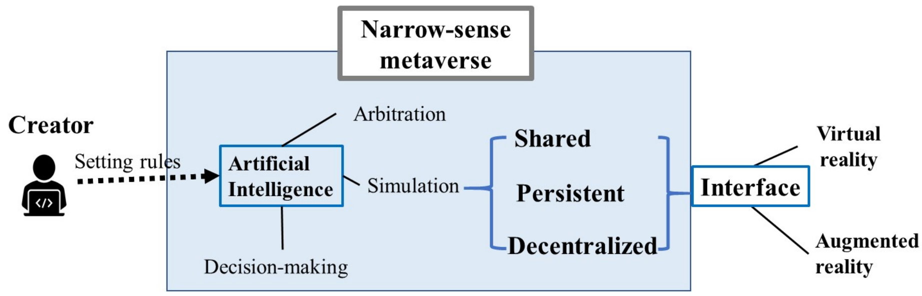

Figure 1 Framework of the narrow-sense metaverse

Hwang and Chien (2022) have proposed numerous potential research topics related to the narrow-sense metaverse in education:

(1) *Creating metaverse-based educational models and execution frameworks, including proposing metaverse-based learning strategies, designing metaverse training programs that are challenging to simulate in real-world contexts, and using the metaverse as an assessment approach*. The metaverse offers new possibilities for education, including the development of educational models and frameworks, as well as the creation of educational institutes and practicing spaces. It also offers new ways to assess learners' higher order thinking competences, and provides opportunities for learners to participate in costly or risky training programs.

Furthermore, the metaverse offers alternative learning strategies and supports, such as helping learners with the concept mapping process or providing them with opportunities to encounter authentic situations that are challenging to simulate in the actual world. The metaverse offers cost-effective and accessible professional training programs, as learners can practice various operations on 3D models and receive immediate feedback and assistance with the help of AI.

(2) *Exploring how metaverse-based learning affects academic achievements and perspectives of learners with different personal features, and investigating their behavioral patterns*. One promising research topic for educational technology and computer science researchers is exploring the impact of metaverse-based learning on learners' cognitive and affective performances. Researchers can better understand the advantages of the metaverse by comparing the results of learners utilizing metaverse-based approaches with those using conventional technology-enhanced learning methods. Additionally, AI technology can enable learners to have more flexibility in their learning experiences, while also receiving support and guidance based on their learning logs. Further research should explore how learners with varying personal characteristics perceive and benefit from metaverse-based learning. Finally, analyzing learners' behavior and interactions in the metaverse can provide valuable insights into their achievements, and help teachers develop individualized learning strategies. The abundance of data collected from physiological and behavioral sensors in the metaverse, including eye and head movements, can offer valuable insights into learners' attention allocation, cognitive states, and psychological activity.

(3) *Associating the metaverse to the current pedagogical theories or reconsidering the theories by integrating the characteristics of the metaverse and discovering novel roles of AI in such learning contexts.* The metaverse presents a new opportunity for educators to explore pedagogical theories and develop new approaches to learning. In order to effectively use the metaverse for educational purposes, educators must consider its unique features, such as its shared, persistent, and decentralized nature. Additionally, AI can play a new role in the metaverse, acting as an NPC tutor, tutee, or peer. For instance, an NPC tutor can provide immediate feedback and suggestions to EFL students regarding their English writing skills. However, learners' perceptions of AI in the metaverse may differ from their experiences with AI applications in the real-world context. As such, educators should explore the advantages and the problems to be coped with when utilizing AI in the metaverse for educational purposes.

(4) *Applying ethical principles when utilizing the metaverse in educational environments*. To ensure responsible use of the metaverse for education, it is crucial to define ethical principles for its implementation. The metaverse is more than just a game or a form of entertainment; it constitutes a multifaceted society. Although it servers as an efficient learning mode, it also gives rise to ethical concerns like privacy infringement, bullying, cheating, and educational inequality. To tackle these challenges, scholars, teachers, and policymakers should examine the ethical issues and employ technological or policy solutions, such as AI modules or ethical codes for user behavior in the metaverse.

3 Broad-sense definition

From the perspectives of school education and professional training, the narrow-sense definition of the metaverse could be unrealistic. For example, the “persistent” future generally cannot be applied to most cases for school education and professional training, in which the learning time of each course needs to be scheduled (Chen, 2022). Similarly, the “decentralized” features might not be crucial since schools or institutes already have their own credit-recording systems. Moreover, for some learning programs, the use of immersive devices or 3D contexts might not be necessary owing to some realistic considerations, such as the computing power of the computers and the health condition of the learners (Freina & Ott, 2015). Therefore, from an educational perspective, the definition of the metaverse could be quite different from the narrow-sense definition.

Figure 2 shows the framework of the broad-sense metaverse, in which “shared” and “interactive” features are the main concerns; moreover, in addition to VR and AR, conventional online learning systems can be used to engage learners in the metaverse. Several studies have been implemented based on this broad-sense definition. For example, several researchers have engaged learners in the metaverse using an AR or VR interface for healthcare education (Butt et al., 2018; Huang et al., 2018), scientific inquiry (Lai, 2022) and language learning (Chen, 2021). Recently, some studies have reported the implementation of the metaverse using Gather Town (Chang, 2022), which is an online virtual learning environment with a 2-D interface, implying that a 3D interface and the use of wearable devices are optional in the broad-sense metaverse. Owing to the easy-to-implement and low-cost features, such a broad-sense metaverse-based learning approach is becoming popular in all levels of educational settings. For instance, Chang et al. (2022) implemented an online virtual learning environment via Gather Town to emulate a real-life clinical learning environment to train nursing students. They reported that the nursing students using the proposed approach perceived better learning achievement, self-efficacy, engagement, as well as learning satisfaction.

It should be noted that the broad-sense metaverse is different from a conventional AR or VR application. From Figure 2, the broad-sense metaverse emphasizes “shared” and “interactive” experiences in the virtual environment, while most conventional AR or VR applications focus on personal experience in virtual contexts. That is, multiple users and interactions between users are the key foci of the broad-sense metaverse. The point is, can people immersed in the virtual contexts share and interact with others?

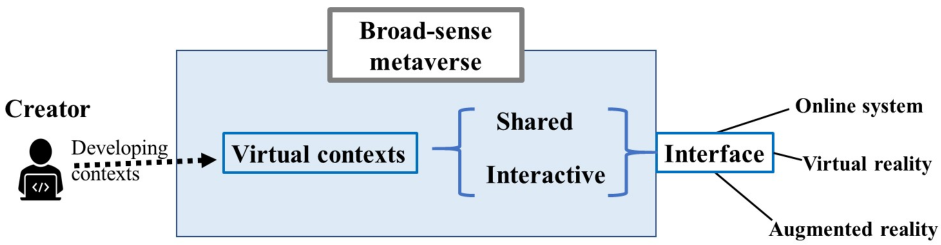

Figure 2. Framework of the broad-sense metaverse.

Owing to the pandemic and the advancement of communication networks, a growing number of meetings, collaborative projects, and learning activities are likely to be conducted in the broad-sense metaverse. From the perspective of education, there could be more potential applications of the broad-sense metaverse than those of the narrow-sense metaverse since educational programs are generally well scheduled, either in school settings or enterprise training; in particular, it is expected that the learning outcomes will benefit the learners in their real life. There are several reasons to engage learners in the broad-sense metaverse:

(1) To exchange ideas among people who are not able to meet physically owing to practical limitations, such as physical locations or the pandemic. An example of this item is the online international conference conducted in a metaverse system in which people from different countries can show their works and exchange ideas during the pandemic. One frequently adopted metaverse system is Gather Town, in which an individual researcher can have a place to present their studies, and people who attend the conference can "walk" in the "conference venue" to find the presentations they are interested in.

(2) To collaboratively complete a project with people who are not able to meet physically. This frequently happens when the members of a work team are not physically together, but need to interact and exchange ideas to complete the work. Unlike traditional online collaborative working, metaverse-based working enables team members to collaboratively complete the work as well as have discussions, just like when they are physically together.

(3) To learn new knowledge or skills from people who cannot physically meet. Traditional online learning also enables us to learn from someone whom we cannot physically meet; nevertheless, it is difficult to demonstrate and practice some complex procedures or skills in this learning mode. The metaverse-based learning mode is a good solution to cope with this problem.

(4) To learn new knowledge or skills that are unable to be experienced physically owing to risky considerations. Traditional VR systems also enable learners to experience or practice in those risky contexts; however, in a VR system, learners generally learn on their own with the guidance of the system. When the experience or practice requires the assistance of peers or tutors, or needs to be practiced collaboratively, the metaverse-based learning mode is a better choice. In several application domains, such as nursing training, medical training, military training, and scientific inquiries, the metaverse-based learning mode could be very helpful to avoid situating learners in dangerous situations.

(5) To learn new knowledge or skills that cannot be experienced physically owing to practical constraints. This occurs when it is difficult to research the physical learning contexts. For example, it is difficult for EFL (English as Foreign Language) learners to experience living in an English-speaking country. Another example is that, in a science course, it is not possible to enable students to explore the moon.

To sum up, there are numerous promising ways of using the metaverse in educational settings. The aims of adopting the metaverse, especially the broad-sense version, are generally owing to the need to situate learners in contexts they do not have the chance to experience or practice physically, or the cost of learning in the physical world is too high to accept. The use of VR could partly respond to these needs; however, the metaverse is able to provide a better solution by taking into account the importance of interactions between peers and tutors in the virtual world.

4 Roles of emerging technologies and pedagogical theories

When planning an educational technology study, researchers need to consider the technologies to be adopted and the pedagogical theories to support the research plan as well as the application domains, participants, and research foci (Ross et al., 2010). Similarly, in a metaverse-based learning study, it is important to figure out what kind of technologies and theories could be included in the study. From the definition of the narrow-sense metaverse, it is apparent that AR or VR plays the role of presenting the virtual content, while AI plays the role of managing the virtual world. However, from the definition of the broad-sense metaverse, AR, VR and AI are optional. This could be good news for those non-technological background researchers who intend to conduct metaverse-based learning research, since the cost and technological barriers are much lower than those of the narrow-sense one.

In terms of pedagogical theories, there are several theories that support the use of the metaverse in education:

(1) Situated learning theory. It is an instructional approach emphasizing that learners are more willing to learn when situated in real contexts to experience and explore (Brown et al., 1989). Several researchers have indicated that situating learners in real-world contexts would help them realize the meaning of learning and the learning content (Özüdogru & Özüdogru, 2017). In the past decade, educators have conducted various learning activities based on the situated learning theory, such as field trips, collaborative projects, internship experiences, and laboratories (Bell et al., 2013; Pfeiffer et al., 2009; Sweeney & Paradis, 2004; Zakrajsek & Schuster, 2018). However, such real-context activities are frequently limited by the cost and safety considerations (Chatigny, 2022). The metaverse provides an alternative to fulfil the situated learning theory by providing authentic virtual contexts to replace the real ones.

(2) Social constructivism. It refers to a sociological theory emphasizing that knowledge is constructed through interacting with others (Hsu & Ching, 2012; Vygotsky, 1978). It is apparent that this theory perfectly meets what happens in the metaverse-based learning environment that engages learners in interacting with peers and tutors as well as exploring and acquiring knowledge in the virtual contexts.

(3) Experiential learning theory. It emphasizes learning from experience; that is, learning is the process of constructing knowledge via gaining and transforming experience (Kolb, 1984). To provide learners with opportunities to experience, authentic contexts play an important role. However, in some application domains, it is challenging or not possible to situate learners in real contexts by considering cost or safety issues, and hence the metaverse could be a good choice. From this perspective, metaverse-based learning is a good choice to fulfil the objective of experiential learning.

5 Research Topics from the Broad-Sense Perspectives

In recent years, the advancement of computer and network technologies as well as wearable devices has sped up the progress of metaverse applications. In the meantime, the number of relevant educational technology research topics is increasing at a fast pace. Several new journals, such as “Computers & Education: Artificial Intelligence” and “Computers & Education: X Reality,” have been published. This implies that researchers and publishers have identified the potential of the metaverse in education. However, most of the existing studies published in well-recognized journals mainly focus on AR, VR or AI in educational settings; only a few studies have referred to the notation of the metaverse. To encourage researchers to engage in metaverse-based learning studies, some potential research topics are presented in the following.

(1) Investigating the impacts of adopting the metaverse for group discussion or brainstorming activities on learners’ higher order thinking (e.g., reasoning, analyzing or creative thinking), learning performances, perceptions (e.g., sense of presence, learning motivation or engagement) and behaviors. It has become a new trend to have group discussion in virtual environments. For example, online meetings or conferences have been frequently conducted since the pandemic. It is interesting to see whether the learners situated in the metaverse show better higher order thinking, learning performances, perceptions and behaviors than those learning with the conventional online discussion. From the perspective of situated learning theory, immersing learners in more authentic contexts could encourage their learning engagement. From the perspective of social constructivism, more engagement and interactions are likely to lead to better learning performances.

(2) Comparing the effects of metaverse-based learning mode and conventional online learning mode on learners’ collaborative project outcomes and perceptions (e.g., learning motivation and collective efficacy). The findings could be valuable to those who cannot physically meet, but need to collaboratively complete projects, such as some international collaboration. Similarly, the experimental results can be explained by the situated learning theory or social constructivism.

(3) Investigating the effectiveness of adopting the metaverse for learning to deal with complex problems or practicing complex skills. As mentioned above, the metaverse could be useful when learners and tutors are unable to meet physically. In conventional online learning, it is sometimes challenging for a tutor to demonstrate and guide learners to practice for a complex procedure or skill. The authentic contexts provided by the metaverse could serve as a viable solution to tackle this issue since, in a well-designed metaverse, people could operate on something together, just like they are physically together. Therefore, in such research, it would be reasonable to compare the skills or problem-solving competences of the learners using the metaverse and conventional online learning approach.

(4) Applying the metaverse to the educational domains, in which the events rarely occur or are highly risky. For example, in nursing or medical education, some urgent conditions rarely occur, and hence in the traditional instruction mode, the

tutor generally uses a video to introduce a case, and then asks the tutees to discuss how to deal with the case and report the results on a learning sheet. In such a training mode, the learning performances of the tutees could be disappointing since they lack opportunities to experience or deal with the case. Adopting the metaverse-based training mode can cope with this problem. In the metaverse, the tutees have opportunities to experience or even try to deal with the case in the virtual world with the guidance of the tutor. Therefore, it is expected that the tutees learning with the metaverse would have better performances than those learning with traditional instruction. The experimental results could be supported by the experimental learning or satiated learning theory since the use of the metaverse provides opportunities for tutees to experience in authentic contexts.

(5) Applying the metaverse to educational domains in which learners are unable to experience some specific contexts due to practical constraints. As mentioned above, in some situations, learners are unable to physically visit some places owing to the cost or time considerations. A frequently found example is English courses for EFL learners. It would cost a lot for them to physically visit an English-speaking country to practice their English. In such a case, learning to listen to and speak English in the metaverse could be a better choice than conventional online learning or traditional instruction. From both the perspectives of situated learning and experiential learning, practicing English in an authentic English-speaking environment is crucial to EFL learners.

(6) Incorporating effective learning strategies or tools into metaverse-based learning. The metaverse mainly provides authentic contexts for learners to experience, explore and interact with. In this learning mode, the provision of personal guidance or support is generally required. There are various learning strategies or tools that might be included in metaverse-based learning, and researchers can adopt suitable ones based on the educational objectives or the features of the learning content. For example, it could be a good idea to guide learners to organize what they have experienced or discussed in a concept map in a metaverse-based scientific inquiry since several previous studies have reported the effectiveness of using graphic organizers, such as concept maps, in information-rich contexts (Billert et al., 2022).

(7) Examining the effectiveness of metaverse-based learning from diverse perspectives. In addition to learning achievement and motivation, there are several potential research foci that can be measured to show the effectiveness of engaging learners in metaverse-based contexts, such as the learners' sense of presence (Makransky & Petersen, 2019), immersion (Makransky & Mayer, 2022), self-efficacy (Lo & Tsai, 2022), communication awareness (Lee & Hwang, 2022), collaboration awareness (Jovanović & Milosavljević, 2022), problem-solving tendency (Hwang, 2023), critical thinking (Yang & Kang, 2023), creative thinking (Lin & Wang, 2021) as well as their learning behaviors and interactive behaviors (Ugwitz et al., 2021). The research foci are determined based on the adopted strategies, tools, or the application domains. For example, in a metaverse-based nursing training problem, the foci could be the case analysis and reasoning abilities since the program aims to foster learners' competence of making correct judgements on clinical cases; for another nursing training program, the foci could be nursing skills and self-efficacy since the learning content is about complex nursing skills, which are challenging to

most learners in traditional instruction. The use of additional learning strategies or tools could also be the reason for taking some research foci into account. For example, incorporating the self-regulated learning strategy into metaverse-based learning could improve learners' meta-cognition, while adopting the gamification strategy could increase learners' motivation and flow experience; therefore, it is reasonable to include these issues in the studies.

(8) Finding stakeholders' acceptance and perceptions of the metaverse-based educational mode. When a new technology-based educational mode is proposed, perceptions of the stakeholders, such as students, teachers, parents, and school administrators, would determine the success of using this new educational mode. As there could be concerns from different stakeholders, it is important to realize their attitudes toward the adoption of the metaverse in education. For example, parents might worry whether their children would indulge in the virtual environment, teachers might be afraid that they are unable to manage the new learning system, and school administrators might worry about the cost of using the metaverse system. With proper research designs using some theoretical models, such as Technology Acceptance Model or its extended models (Fussell & Truong, 2021; Kemp et al., 2022), the factors affecting those stakeholders' acceptance or perceptions of the metaverse could be found, and further communications or policies can be made to resolve the potential problems and barriers.

6 Conclusions

In this paper, we have attempted to define the broad-sense and narrow-sense metaverse, and to highlight the pedagogical theories related to the metaverse-based learning. For researchers who intend to conduct research in this direction, it is important to identify the features of broad-sense metaverse, narrow-sense metavers, and conventional VR/AR-based learning. Table 1 summarizes the three learning modes. From the table, it can be realized why many educational technology researchers have hesitated to engage in the metaverse in education studies: they consider that the cost and technical requirements for developing the narrow-sense metaverse are too high to afford. Indeed, so far, most systems that meet the standard of the narrow-sense metaverse are developed by companies with high computing techniques, such as some well-known game companies. For researchers or school teachers who are not experts in computer programming, a low-cost combination for developing a broad-sense metaverse or an AR/VR system could be a better choice. In fact, for most instances of school education or professional training, using a broad-sense metaverse or even an AR/VR system could be good enough. It should also be noted that the broad-sense metaverse with 2D contexts, such as Gather Town, has the least requirements of a metaverse.

Table 1. Comparisons of broad-sense metaverse-based learning, narrow-sense metaverse-based learning, and conventional VR/AR-based learning

	Narrow-sense metaverse	Broad-sense metaverse		Conventional VR/AR
		3-D contexts	2-D contexts	

Shared	Yes	Yes	Yes	Optional
Interactive	High	High	High	Low
Persistent	Yes	Optional	Optional	Optional
Decentralized	Yes	Optional	Optional	Optional
Supported by AI	Yes	Optional	Optional	Optional
Immersive	Yes	Optional	No	Optional
Technical	High	Medium	Low	Low-to-medium
Cost	High	Medium-to-high	Low-to-medium	Low-to-medium

To sum up, from the perspective of educational objectives, whether a system is the metaverse is not important. What educational technology researchers need to be concerned about is whether the system or technology can benefit learners. The aim of this paper is to encourage researchers to put efforts into the metaverse in education studies since situating learners in authentic contexts could be of great benefit to them, as indicated by the situated learning and experiential learning theories as well as social constructivism. It is believed that a growing number of metaverse-based learning studies will be reported by researchers in the coming years.

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