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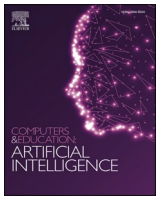

Definition, roles, and potential research issues of the metaverse in education: An artificial intelligence perspective

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ABSTRACT

The metaverse has been recognized as one of the technologies with the greatest potential today. However, the use of the metaverse for educational purposes is seldom discussed. Most educators might be unaware of the features of the metaverse, not to mention the potential applications of this emerging technology. In this position paper, we aim to provide a clear definition of the metaverse. Potential applications and research issues of the metaverse in educational settings are also presented. Moreover, the roles of AI in the metaverse as well as metaverse-based education are discussed. It is expected that, via this paper, researchers from the fields of both computer science and educational technology would have a clear picture of what the metaverse is and how it can be used for educational purposes. More importantly, it is expected that more studies related to metaverse-based education can be reported in the near future.

1. Definition and applications of the metaverse

The metaverse has been recognized as being the next generation of social connection. It refers to a created world, in which people can "live" under the rules defined by the creator (Farjami et al., 2011 September; Kye et al., 2021). A metaverse could be fully or partially virtual; for example, it could be a fully virtual world like a virtual reality (VR) system, or a partially virtual world like the use of augmented realty (AR) in real-world contexts (Avila, 2017). In the metaverse space, people can engage in social activities such as discussing an issue, collaborating on a project, playing games, and learning from experiencing or solving some problems (Bourlakis et al., 2009; Jovanović & Milosavljević, 2022; Park & Kim, 2022). One's partners or friends in the metaverse could be real persons or virtual characters (Díaz et al., 2020; Kye et al., 2021). Moreover, there can be various kinds of activities or events in the metaverse just as in the real world, such as economic activities, political events, and natural disasters (Davis et al., 2009; Díaz et al., 2020). In such a virtual world, the only limitation is people's imagination. Moreover, with the lifelogging function, the details of life in the metaverse can be fully recorded (Thawonmas & Fukumoto, 2011).

Some people might consider the metaverse to merely be a new term for VR or AR; however, it is much more than AR or VR (Park & Kim, 2022). Fig. 1 shows the framework of a metaverse. There are three features of the metaverse that make it quite different from conventional VR or AR: "shared," "persistent," and "de-centralized." Moreover, artificial intelligence (AI) is a required technology to enable the world of the metaverse to work following the rules defined by the creator. From this framework, it can be seen that an AR or VR system could be part of the metaverse for presenting the virtual content; on the other hand, the metaverse could contain AR or VR elements plus other required elements. Regarding the feature of "shared," a student learning with a VR training system alone cannot be considered as an example of the metaverse in education. In a multi-user VR system, such as Second Life, people can interact with others using a new identity; however, if the system is unable to provide a persistent world enabling users to "live," such as working, owning, learning, interacting, creating, and entertainment, it is not a metaverse from the perspective of "persistent." Moreover, decentralized technologies (e.g., blockchains) are required to ensure that the economic activities can be safely conducted and that personal property and logs in the metaverse will not be modified by others (Min & Cai, 2022).

In recent years, many applications related to the metaverse have been reported around the world, in particular, by the companies of computer games and social networks (e.g., Facebook) (Egliston & Carter, 2021; Jeong et al., 2022; Kye et al., 2021; Wiederhold, 2022). Moreover, several emergent technologies, such as wearable devices, could also be used in the metaverse (Cipresso et al., 2018). For example, CEO of Meta Platforms, Mark Zuckerberg, labeled the head-mounted

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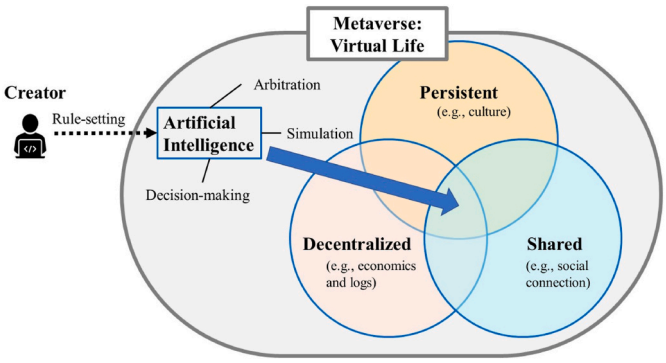

Fig. 1. The framework of a metaverse.

display (HMD), Oculus, as a "social computing platform" (Egliston & Carter, 2021). Moreover, scholars have indicated that, in addition to VR and AR, the advancement of brain-computer interfaces (BCI) will further facilitate the adoption of the metaverse (Mystakidis, 2022).

In recent years, issues and applications of the metaverse have been widely discussed. Several institutes or articles have claimed that there are several applications of the metaverse. The most frequently mentioned application is digital games (Park & Kim, 2022). Another well-known application is healthcare, for example, using AR or VR to engage students in medical or nursing skills training (Huang et al., 2021; Hwang et al., 2022; Zhang et al., 2021). AR or VR have also been used to showcase some new products or to provide virtual experiences (Bourlakis et al., 2009). In addition, using AR or VR for military training is another example frequently mentioned by previous metaverse articles (Díaz et al., 2020). From the perspective of a strict definition of the metaverse, most existing applications are in fact AR or VR rather than the metaverse. On the other hand, the effectiveness and success of these applications set the potential of the metaverse. Of course, to implement ideal metaverse applications, the features (i.e., "shared," "persistent," and "decentralized") need to be taken into account. For example, a metaverse gaming environment should allow multiple players to participate in the game to fulfil the "shared" feature; moreover, individual players can continuously play the game to follow the "persistent" feature. More importantly, the gaming environment needs to guarantee that the players can work for and own their own properties or treasures, and their logs must be safely kept using some secure technologies, such as blockchains, to fulfil the "decentralized" feature (Vergne, 2021).

Meanwhile, it is important to know that AI generally plays an important role in the metaverse. To ensure that the "world" of a metaverse functions following the rules defined by its creator, AI technologies are needed. "Arbitration" is one of the functions executed by the AI module when there are conflicts among the users of the metaverse. For example, in a metaverse-based game, there are likely to be competitions or fights; thus, arbitration is needed to judge who wins and who loses as well as determining the consequences. "Simulation" is another possible function provided by the AI module. For example, when a user grows plants or raises animals, there is the need for a simulation function to determine the status of the plants or animals as time passes. An even more important usage of the "simulation" function provided by AI technologies is that it enables the NPCs (Non-player characters) to act like humans in the metaverse. Of course, the AI module also needs to be able to make decisions following the rules pre-defined by the creator, such as determining the consequences when some events happen based on the pre-defined rules.

2. Roles of the metaverse in education from the perspective of AI

As indicated by scholars, there are several potential applications of the metaverse in education, such as medical, nursing, and healthcare education, science education, military training, and manufacturing training as well as language learning (Choi & Kim, 2017; Díaz et al., 2020; Jovanović & Milosavljević, 2022; Koo, 2021; Siyaev & Jo, 2021; Tasa & Görgülü, 2010). Owing to the features of the metaverse, it is expected that the metaverse in education is different from the traditional VR- or AR-based education.

For example, for a language learning course for EFL (English as Foreign Language), the effectiveness of situating the learners in authentic contexts provided by VR has been reported by several previous studies (Chien et al., 2020). However, from the perspective of the metaverse, the aim of language learning is more than a course or a learning activity; instead, it aims to enable EFL learners to have another life, a living environment using English for working, learning, social events and entertainment, just as if they were native English speakers. The two learning experiences (i.e., VR and the metaverse) are quite different.

Another example is using AR in skills training, such as the study reported by Webel et al. (2013). In such an AR-based training mode, the learners were merely supported by AR in a short-term (i.e., 60 min) activity to complete a specified skill practice. In comparison, from the perspective of the metaverse, this could be done better; for example, if the learners were pre-service trainees in a professional training institute, they could take a formal training program with instruction from a NPC master, say for 3 months, to experience the authentic training process rather than a short-term activity that is far from a practical training situation.

Therefore, from the perspective of AI, there are several roles of the Metaverse in education, namely, the provision of an authentic world that enables learners to "work" and "learn" with intelligent NPC tutors, peers, and tutees as well as other human learners. Fig. 2 depicts this notation. In summary, the biggest difference between the metaverse and the current application of VR or AR in education lies in the experiencing time and the inclusion of AI technology. First, in the metaverse, students tend to have a life that is separate from the real world and runs for a period of time. The current applications of VR and AR in education tend to engage students in experiencing specific situations over a short time period where they can pause or start over. On the contrary, the metaverse aims to provide an authentic life, implying that the experience inside generally cannot be paused or restarted. In addition, in the metaverse, AI technology is needed to help maintain the authentic world. One can imagine that the NPC characters in the metaverse can "learn (be trained)" after interacting with users and "grow" along with the timeline. Moreover, the NPC characters in the metaverse could remember individual users' dialogue and behaviors after encountering them in the metaverse. On the other hand, in VR, virtual characters usually only interact with users according to the original settings and do not "learn" from users' interactions.

From the perspective of education, the roles of AI in the metaverse are very important. As indicated by Huang et al. (2021), there are three roles of AI in providing educational services in addition to the roles of supporting arbitration, simulation, and decision-making in the

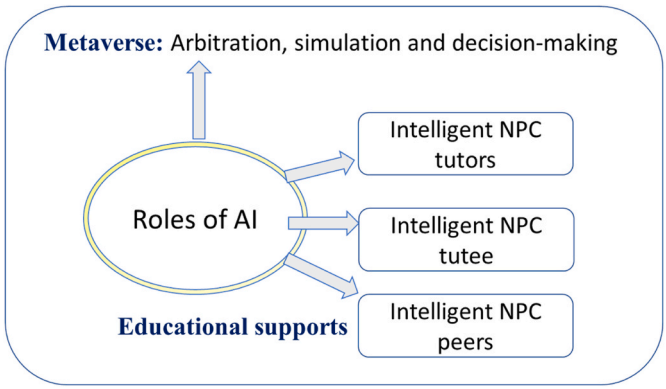

Fig. 2. Framework for the metaverse in education.

metaverse:

(1) NPC tutor or advisor. In the metaverse, users can generally seek help or advice from other users who are knowledgeable or experienced. However, in some particular or professional domains, advice from some "wise" or "experienced" NPCs could be required. For example, it is quite possible that the learners cannot find a user to help them resolve the problems related to a medical problem in the metaverse world. In this case, the role of an intelligent NPC who is capable of solving medical problems is very important. Of course the instructor can be a user to do this; however, he/she cannot always be there to help every learner.
(2) NPC tutee/student. Some researchers might consider that this role of AI in the metaverse could be unnecessary since the learners can generally interact with other learners and seek help from or provide advice to others. However, it is also possible that some learners need to practice teaching others or learn to be a mentor. This implies the need to have someone who can constantly be their trainees. For example, for a learner who is a pre-service teacher, he/she might need to practice his/her class-management or learning-design skills, and it is almost impossible to find a class to do this. In this case, it is important to have a class of NPC trainees/students in a school in the metaverse world.
(3) NPC peer. This role is very important from the perspective of social constructivism (Kalina & Powell, 2009). In a learning environment, it is always necessary for learners to interact with peers. An ideal case is that several users are experiencing and learning in the same contexts for the same educational purposes, so that they can discuss with each other during the learning process. However, this could not always be the case. Thus, NPC peers are needed; in particular, those NPC peers who can be a role model for the learners.

3. Potential applications of the metaverse in education

There are various potential applications of the metaverse in education, such as medical, nursing, and healthcare education, science education, military training, and manufacturing training as well as language learning. In fact, the metaverse enables learners to have more opportunities to experience, explore, learn, and teach in a new world, as well as working and interacting with people. They can even learn or practice in those contexts they are unable to experience in the real world. For example, most people might not have opportunities to serve at the managing level or practice to fly a plane. However, this could happen in the metaverse if the creator aims to provide the experience or learning opportunities to the users. Therefore, there are many potential applications of the metaverse in education. Without the loss of generality, several reasons for adopting the metaverse for educational purposes are listed as follows:

(1) To constantly situate learners in a cognitive or skill practicing environment that could be risky or dangerous in the real world.
(2) To constantly situate learners in the contexts to experience and learn what they generally do not have the opportunity to be involved in the real world.
(3) To enable learners to perceive or learn something that requires long-term involvement and practice.
(4) To encourage learners to try to create or explore something that they cannot afford to do in the real world owing to some practical reasons, such as the cost or the lack of real materials.
(5) To enable learners to have alternative thoughts and attempts regarding their careers or lives.
(6) To enable learners to perceive, experience, or observe things from different perspectives or roles.
(7) To enable learners to learn to interact and even collaborate with people that they might not have opportunities to work with in the real world.
(8) To explore the potential or higher order thinking of learners by engaging them in complex, diverse, and authentic tasks.

Accordingly, it can be seen that there are many possible applications of metaverse-based education. The purposes of learning in the metaverse could be highly related to the learners' needs in real life if they do not have opportunities to experience or practice in the real world. Alternatively, metaverse-based education could be totally irrelevant to the learners' occupations or majors in the real world; they might just want to try something new or play a different role to see what they can do in a totally different professional direction in the metaverse.

4. Potential research topics for the metaverse in education

As mentioned above, there are many reasons for adopting the metaverse in educational settings. Owing to the rapid advancement of relevant technologies related to the metaverse, such as wearable devices, high-speed computers and networks, and sensing technologies, using the metaverse for educational purposes is becoming increasingly possible. From the fast growth of the numbers of AR, VR, and AI studies published in well-recognized educational technology journals such as Computers & Education, the British Journal of Educational Technologies, Interactive Learning Environments, Educational Technology Research & Development, and Educational Technology & Society, it is predicted that the number of articles related to the metaverse in education will increase in the coming years. To enable researchers who intend to be engaged in this research field, some potential research issues of the metaverse in education, which are proposed with reference to several position papers on education technologies (e.g., Hwang, 2014; Hwang et al., 2020; Kimmons et al., 2021), are listed as follows:

(1) *Developing metaverse-based educational models or execution frameworks.* So far there is no particular model or framework for developing a metaverse world. This implies diverse possibilities for developing metaverse-based environments for different educational purposes and applications. On the other hand, a metaverse could serve different educational purposes since it is a "world" that could contain several educational institutes (e.g., schools, universities, and professional training institutes) or practicing spaces (e.g., science parks, hospitals, and museums). It is expected that, by including educational institutes and practicing spaces, learners can receive full training programs and corresponding certificates after completing the training programs. More importantly, learners are able to participate in some training programs they might not have opportunities to attend in the real world, such as some high-cost or high-risk programs.
(2) *Investigating the effects of metaverse-based educational environments on learners' learning performances and perceptions.* This could be the most adopted research theme for researchers in the coming years. As the metaverse is such an innovative technological environment for researchers from the fields of both computer science and educational technology, it is important to compare the performances of learners using the metaverse-based educational approach and those using the conventional technology-enhanced learning approach. From the perspective of AI technology, it is also expected that, by adopting the metaverse-based educational approach, learners can have continuous learning opportunities without being limited by space and time, as well as receiving full support or guidance for making reflections based on the analysis results of their learning logs.
(3) *Employing the metaverse as an assessment approach.* Evaluating learners' higher order thinking competences, such as problem solving and critical thinking, is generally a challenging task. It is

difficult to perform the evaluation based on a test. Observing and assessing learners' problem-solving or project-completing processes could be a promising direction. In the metaverse, learners' logs for solving problems or completing projects are recorded. This implies that their performances or competences can be more accurately evaluated from diverse dimensions. Moreover, the metaverse enables evaluations that could be risky in the real world, such as the competence to perform surgery or fly a plane. That is, the metaverse provides not only opportunities for learners to practice, but also alternative ways for assessing their competences.

(4) *Connecting the metaverse to the existing pedagogical theories or redefining the theories by taking into account the features of the metaverse.* It can be foreseen that educators need to refer to some pedagogical theories when trying to use the metaverse in a proper way or from a proper perspective. It is important to consider the features of the metaverse (i.e., shared, persistent, and decentralized) as well as the roles of AI in the metaverse (i.e., NPC tutor/advisor, NPC tutee/students, and NPC peers). For example, based on the feature "shared," social constructivism, which emphasizes that one's knowledge is constructed through social interactions, could be a good choice for supporting the use of the metaverse in educational settings.

(5) *Proposing metaverse-based learning strategies.* Employing the metaverse as an educational environment implies the potential to perceive learning designs from new perspectives. As a consequence, it is crucial to reconsider roles of the existing learning and assessment strategies in the metaverse. For example, what would a concept map look like in the metaverse? Could the process of concept mapping in the metaverse be different from that in the real world? For instance, in the real world, students need to develop a concept map based on their own comprehension with the concepts to be included, and search for relevant data using a computer. On the other hand, in the metaverse, the system may provide supports to assist users during the concept mapping process, such as recording the objects they have observed in the metaverse and enabling them to search for relevant data through eye-movement technology and voice recognition technology as well as automatically organizing the objects or ideas they express. Another example is inquiry-based learning; it is quite possible to implement an inquiry-based learning activity that cannot be conducted in the real world owing to the limitations of time and location. For example, in conventional business management courses, it is expected that learners can experience the process of managing electronic business by observing the market, collecting data, analyzing the data and making decisions; however, it is not possible to provide them with opportunities to make actual business decisions in real-world contexts since the cost could be huge. In the metaverse, learners are provided with authentic situations that allow them to experience the whole business process and make decisions, and then experience the relative consequences of their decisions. During this authentic process, learners are able to collect data and make plans in virtual meeting rooms with other learners or the NPC characters. They also need to work to prepare funding or to apply for loans for their business from the bank. After making a decision, they need to face different consequences including the events which occur in the market and the decisions made by other users in the metaverse, just as would happen in the real world.

(6) *Examining learning performances and perceptions of learners with different personal features in metaverse-based contexts.* When adopting a new technology for educational purposes, many personal factors, such as learners' knowledge levels, cognitive styles, preferences, learning motivations, self-efficacy, and learning attitudes, could affect their acceptance or performance in the new technological contexts. As the metaverse is a very new concept in educational settings, it is worth investigating how learners with different personal features perceive the new learning environment and whether they can benefit when engaging in the new contexts.

(7) *Analyzing behavioral or interactive patterns of learners with different achievement levels in the metaverse.* Within the metaverse, learners' behaviors and interactive content can be recorded. The AI technology (e.g., machine learning and statistical analytics methods) can be used to analyze the data for several purposes. For example, the analysis results can be used to advise individual students by developing a behavioral model based on those high achievers or those who make significant progress. The analysis results can also enable the teachers or policy makers to perceive learners' learning status from both macro and micro perspectives. In addition, AI technology is able to analyze the data to predict the relationship between learners' inputs and outputs. Although in conventional technology-enhanced learning contexts, similar analysis can also be applied, the data collected in the metaverse could be quite different from those in conventional technology-enhanced environments, such as VR systems or digital games. In the metaverse, the data are continuously collected; moreover, they are collected from a variety of physiological or behavioral sensors, such as eye movement, gaze information, eye blink rate, head or controller (hand) movement and orientation as well as their interactive content and conventional learning behaviors (e.g., clicking an item in a menu or reading a web page). These additional data could be highly informative. For example, head movements imply attention allocation at the macro level, while eye movements imply attention allocation at the micro level. Eye tracking can represent visual perceptions and processing. These signals are related to human behavior, cognitive states, and psychological activity. By tracking the head orientation, it is possible to understand the behavioral patterns and conditions of the learner in metaverse environments.

(8) *Developing metaverse training programs that are difficult to implement in real-world contexts.* In the metaverse, professionals and trainees can meet in the collaborative space of virtual assets, such as medical devices, aviation equipment, firefighting equipment, and so on. Being completely virtual and substituting expensive physical equipment or devices, the metaverse environment is a cost-effective alternative for professional training. In addition to the lower cost compared to physical objects, learners can enter the virtual environment for training regardless of time and space limitations. As a 3D simulator, the learner practices various operations on the 3D model as if they were operating on the actual object. With AI technology, the metaverse environment can provide learners with instant feedback (i.e., audio, visual, vibration feedback) on the environment to achieve the same effect as in real-world contexts. It can also provide learners with immediate assistance and prompts to enhance learning and training effectiveness.

(9) *Defining ethical principles for employing the metaverse in educational settings.* Due to the richness and powerful technology of the metaverse, it should be seen not just as a game or experience, but as a highly complex community. While the use of the metaverse for educational purposes provides an effective learning mode, it could also raise potential ethical issues, such as privacy offending, bullying, cheating, and educational inequality. In addition, it is also questionable whether avatars can represent individual consciousness in the metaverse. For instance, when interviewing a user, who is the interviewer actually interviewing: the avatar or the real individual behind the avatar? In other words, do the actions and behaviors of the avatar originate from the real individual, or does the real individual give the avatar a new role? It is important for scholars, teachers, and policy makers to seriously consider potential ethical issues and cope with these problems

using technological solutions (e.g., using an AI module to resolve ethical problems) or policy solutions (e.g., setting the principles and ethical codes for user behaviors in the metaverse).

(10) *Finding new roles of AI in metaverse-based educational contexts.* In the metaverse, the role of AI is no longer an application or system; instead, AI could be in the form of an NPC tutor, tutee, or peer. For example, in the real-world context, a teacher might encourage EFL (English as Foreign Language) students to use AI applications to check their English writing. With the help of the AI applications, students can derive immediate feedback and suggestions, and have more opportunities to revise the articles and make progress. In the metaverse, AI can do the same by playing the role of an NPC tutor, from which individual EFL students can receive feedback and suggestions regarding their English writing; however, their perceptions could be totally different since in real-world contexts they have the assistance of an AI application, while in the metaverse, they have the assistance of a "tutor." The NPC tutor can even actively take care of individual learners' writing skills rather than waiting for their requests.

5. Conclusions

The presence of the metaverse is going to provide a brand new perspective on educational technology (Díaz et al., 2020; Rospigliosi, 2022). It will provide new training opportunities and contexts for learners. Many training programs or objectives that cannot be achieved in the real world could be conducted in the world of the metaverse (Siyaev & Jo, 2021). In this new world, some barriers that prevent people from learning some materials or skills, such as the limitations of time, space, or even dangers during the learning process, could be overcome (Jeong et al., 2022; Wang et al., 2022). More importantly, with the features of the metaverse, solid training programs with effective learning supports can be provided. It can be foreseen that, in the coming decade, the amount of research and the number of applications related to the use of the metaverse in education will increase at a rapid pace.

On the other hand, there are challenges in creating a metaverse, no matter whether for educational or for other purposes (Davis et al., 2009; Falchuk et al., 2018). In addition to the potential ethical issues mentioned above, the lack of relevant technological supports is a problem at the present (Dionisio et al., 2013). From the perspective of a metaverse creator, a good authoring system as well as powerful computer hardware and high-speed networks are required (Wiederhold, 2022). From the perspective of users, low-cost and lightweight equipment that enables people to continuously immerse themselves in and interact with the metaverse with high-resolution digital content is required (Park & Kim, 2022). Although the cost of relevant equipment (e.g., the headmount) is still high to most people, several companies are trying to develop low-cost solutions. It is predicted that the popularity of the metaverse is only a matter of time. In terms of education, it is important to start considering the potential learning designs and curriculum designs in the world of the metaverse.

Statement on conflict of interest

The authors would like to declare that there is no potential conflict of interest in this study.

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