Metaverse-Based STEM Education for a Sustainable and Resilient Future

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Unit 2: Integrating Technology and Technology linked lessons in the Metaverse

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Introduction

With the outbreak of COVID-19 pandemic our lives have changed dramatically, and a range of activities in the physical world has transited into the virtual world. Telecommuting, online meetings, distance learning, online shopping and some other activities have become a regular part of human life which triggered the need of expanding the boundaries of the physical world to more advanced virtual world. Breakthrough of VR (virtual reality), AR (augmented reality), AI (artificial intelligence), blockchain etc. increased the attention. That might be recognized as the next generation of the Internet, in other words new model of changing how we interact with the world.

As global metaverse research is flourishing, the metaverse has been touted as a future education trend, with great potential (Choi and Kim, 2017; Dwivedi et al., 2022; Gartner, 2022; Guo and Gao, 2022; Hwang and Chien, 2022; Park and Jeong, 2022; Park and Kim, 2022; Rospigliosi, 2022; Shin, 2022; Tlili et al., 2022). The presence of the metaverse usually couples with multiple new technologies (Kang, 2021). However, the literature does not really touch upon the metaverse in regard to education but rather focus on metaverse related technologies in education separately. Majority of the people who are directly involved in the education sector might be unaware of the metaverse technology, its components, and its application in the educational field.

In light of the two axes: ‘augmentation versus simulation’ and ‘intimate versus external’, four scenarios were categorized in the metaverse roadmap: augmented reality, lifelogging, virtual worlds, and mirror worlds (Zhang et al., 2022). This was the idea to describe metaverse before the advancement of the technology. Following the developments in the virtual technologies, different descriptions have emerged. Mark Zuckerberg unveiled his schemes to build Facebook a “metaverse”: an embodied online world where people can present themself, work, play, and socialize with avatars, often in the form of headsets or glasses (Bobrowski, 2021; Zuckerberg, 2021). Similarly, Roblox founder David Baszucki (Jeon, 2021) defined the metaverse as a place that combines high-fidelity communication with a new way to tell stories borrowing from mobile gaming and the entertainment industry. Center for Journalism Studies of Tsinghua University (2021) reported that the metaverse is a created internet application and social form fused with the virtual and real world; it is shaped by integrating many types of new technologies: XR (extended reality) to provide a real and immersive experience, digital twins to map the real world, blockchain to construct credit system, economic system, and exchange system, etc.; it

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realizes the close connection of the social, economic, and identity systems in the virtual and real world, and allows the user to content production and edit in the metaverse (Zhang et al., 2022). Hence, it seems that there is no consensus on the metaverse.

Collection of technologies

The metaverse does not only consist of VR or AR, but rather a collection of novel technologies such as 5G, AI, VR, AR, digital twins, blockchain, holography, or IoT (Internet of Things). The technological framework could be applied for different purposes such as entertainment, commerce, education etc. and based on the purpose components and functions might vary.

Convergence of the virtual and real world

As the metaverse roadmap stated, the metaverse is a fusion of virtually-enhanced reality and physical-persisted virtual space (Smart et al., 2007; Kye et al., 2021), hence, the metaverse is where the items augmented from the real world and the creations produced in the virtual world meets. This convergence enables the possible elimination of the gap between the virtual and the physical world, so that the user's experience in the metaverse more immersive, multi-sensory, and close to authentic.

Rapid and free access

Thanks to high-speed networks such as 5G/6G, users can comfortably utilize smart wearable devices, for instance in form of headsets or glasses, to become a part of the metaverse world without facing any time or location limitations. From this point of view, it realizes free and rapid access for users by switching between the real world and the virtual world remotely and seamlessly (Zhang et al., 2022).

Digital Identity

Instead of a static image, in the metaverse, each user could customize his/her unique digital identity in the form of an avatar (Davis et al., 2009; Dionisio et al., 2013; Park and Kim, 2022). The construction of the digital identity is more user-defined and more advanced than before, for instance, it could edit the details of the avatar's face (Wei et al., 2004), body (Kocur et al., 2020), and even facial expression (Murphy, 2017). This virtual world identity is a means to display the user's persona and represents the ego in the real world. In addition, avatars can be

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manipulated and controlled by users with the help of real-time tracking technologies (Saragih et al., 2011; Genay et al., 2021).

In this case, the living 3D representation of users (i.e., digital identity) plays an important role in ownership, interactivity, embodiment, and socialization in the metaverse world.

Immersive and multisensory experience

In the metaverse, the vivid and colorful virtual scenes modeled by technologies can deliver users a deep feeling of immersion (Shin, 2022; Zhao et al., 2022). With the aid of technologies such as sensors, VR, AR, or IoT, users are allowed to interact with the created virtual items or the items projected from the real world through moving, manipulating, or clicking, thereby greatly motivating users' multiple senses (Koo, 2021; Jovanović and Milosavljević, 2022; Park and Kim, 2022). The metaverse will allow people to be present as if they are in the real world or beyond it, through generating authentic, immersive and multimodal experience.

Decentralized and editable content

Despite the former Internet mode where solely specific groups such as developers possess rights to edit the content, the metaverse create an atmosphere where every user is entitled to edit or generate a content. Just as conceived by Roblox or Facebook (Jeon, 2021; Zuckerberg, 2021), users can create almost everything they can imagine. Additionally, players are also allowed to co-create or modify others' shared content (Taylor and Soneji, 2022). More significantly, users can own and run their own digital properties, and the security technologies, such as blockchain, can ensure their personal properties be safe and traceable (Vergne, 2021; Min and Cai, 2022; Vidal-Tomás, 2022).

Taking abovementioned descriptions into consideration, it is reasonable to state that the metaverse is a 3D digital space mixed with the real and virtual worlds, and neglects the restrictions of the physical world such as time and location. It allows users to engage in a variety of activities (e.g., working, learning, training, socialization, transaction) through avatars and interact with the other players and the virtual objects, as well as provides opportunities for users to edit the content (Zhang et al., 2022). In other words, it offers the users a world in which they can enjoy richer, more immersive, and more embodied experiences than ever.

High-speed communication and networks

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High speed networks and wireless communication are essential requirements for proper metaverse experience. Thanks to these two essential elements, the metaverse can keep fluency, steadiness, and low latency for data transmission, scene presentation, immediate feedback, and user connection.

Computing technologies

Owing to a space gathered by multi-players, the metaverse requires computing technologies (e.g., edge computing, cloud computing, distributed computing) to process, compute, store, transmit, and interchange data and information between the virtual world and the real world, and among users (e.g., Kang, 2021; Zhao et al., 2022). Hence, the learners can store, utilize and share the date efficiently.

Analytical technologies

AI, one of the examples of analytical technologies, possess a great potential for providing intelligent NPC tutors, intelligent NPC tutors, and intelligent NPC peers to facilitate the learning process. With the help of analytical technologies, the metaverse is capable of measuring, tracing, collecting and analyzing the learning data of learners. With this data, personalized resources and services can be offered to the learners.

The technology, the metaverse and the education

The metaverse possess great potential in the education sector due to fusing elements from the virtual and physical world through wearable devices to enter the educational setting without facing any restrictions of time and location.

Students' attitudes toward learning, level of enjoyment, and success on knowledge-based tests are all considered when evaluating them. Through the use of extended reality (XR) technology, the economy, and marketplace are rejuvenated. Similarly to this, Kemp et al. [12] analysed the advantages and disadvantages of a virtual world, which be operated by multiple users simultaneously, in the field of education (Chamola et al., 2023).

Park and Kim (2022) divided the metaverse into three essential components (i.e., hardware, software, and contents) and three approaches (i.e., user interaction, implementation, and application) for the metaverse in a general meaning. Some other scarce proposed work of the metaverse in education is from Hwang and Chien (2022). They discussed the roles (i.e.,

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intelligent tutors, intelligent tutees, and intelligent peers) in providing educational services and potential applications of metaverse for educational settings from the perspective of AI. However, the metaverse is not developed by single technologies, such as AI, but integrated with massive technologies.

Modelling and rendering technologies

The metaverse aims to generate a kind of 3D digital space where the virtual and real world comes together, and include various simulated or mirrored scenes, avatars, NPCs etc. At present, there are several modelling and simulation solutions to create virtual items like Sketch Up, Unity, and Blender (Tlili et al., 2022). The global trend of VR or AR research has also made it possible to construct photorealistic 3D content (Wu et al., 2013; Parmaxi, 2020); however, Park and Kim (2022) believed that the metaverse is much more than VR or AR, but a concept closer to XR. Other scholars (e.g., Lv et al., 2022) mentioned technologies like digital twins, holography, and MR (mixed reality) can also be used to model and render the metaverse world. In light of these opinions, it impossible to ignore the importance of modelling and rendering technologies to build a space that draws learners' attention. Moreover, some scenes or items that can't be offered in the physical world due to various reasons, can be visualized in the metaverse world through these types of technologies.

Interaction technologies

Multimodal interaction is a substantial and unique feature of the metaverse. Interaction technologies like VR, XR, sensors, real-time tracking, IoT, and BCI (brain-computer interface) are necessary for users' manipulations, navigations, collaborations, and sensory feedback (e.g., vision, audition, and kinesthesia) in the metaverse (e.g., Davis et al., 2009; Genay et al., 2021; Prieto et al., 2022). Through integration of this technology, learners might mobilize their bodies in the virtual world to perform learning activities, collaboration, and socialization.

Authentication technologies

Some scholars (e.g., Berg et al., 2019; Vergne, 2021; Thomason, 2022; Yang et al., 2022) stated the most representative authentication technology in the metaverse is blockchain, which can provide transparent, open, decentralized, and reliable services and protect users' privacy to keep the metaverse world to have a sustainable ecosystem. Therefore, blockchain's only purpose is not to make learners' data and works in the metaverse untraceable, but also to prevent fraud and plagiarism from occurring.

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Smart wearable device

The smart wearable device (i.e. headsets, smart glasses, head-mounted displays) is the principal tool that bonds the physical world and the virtual world. Hence, the users can switch between two worlds without any limitations.

Avatar

Avatar represents the user in the virtual world. The support of real-time tracking technology, recognition technology, or simulated technology has made great improvements in the realism of avatars. Both learners and teachers can customize their avatars, with some features (e.g., dressing style, gender, skin color) similar to or different from themselves (Zhang et al., 2022).

Simply put, avatars assist learners in expressing themselves in the way they wish in addition to provide them with a sense of being in the generated metaverse world.

Non-player character (NPC)

NPCs can be displayed in different types in the metaverse world: NPC teachers, NPC learners and NPC peers. These NPCs undertakes fundamental role in supporting, simulation and decision-making for educational purposes. In other words, learners can utilize the NPCs for tutoring, seeking helps, discussing, or practicing skills. Overall, NPCs can enrich the interaction in the virtual world immensely.

Learning scene

Various scenes can be generated through utilization of rendering and modelling technologies such as VR, XR, AR etc. The scenes can be reproduced like real-world classroom layouts in 3D form or constructed as partially or fully virtual scenes according to the learning contents, especially for that cannot be easily seen in the real world, such as universe, marine, forest, historical site, etc. (Wu et al., 2013; Choi and Kim, 2017; Prieto et al., 2022).

Learning resource

Owing to the modeling and rendering technologies, the resources can be visualized in the metaverse, especially for the invisible or abstract concepts, items, or events in the physical world (Dunleavy et al., 2008; Wu et al., 2013). In addition, rest on the interaction technologies such as VR, AR, XR, or sensors, the learning resources can be presented by multimodal means and allow learners to motivate their bodies partly or fully to interact with them, providing them

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with real-time feedback and rich sensory experiences (Chen et al., 2011; Myburgh, 2022; Taylor and Soneji, 2022).

Learning logging

Lifelogging is a substantial part of the metaverse universe, as it is related with the capture, storage, and distribution of daily experiences and information for objects and people. Through lifelogging, learners' progress can be kept track and shared and other relevant information can be stored in the metaverse. It helps both learners and teachers to review or observe the learning process and conduct some meaningful events (e.g., analyzing behavior or interactive patterns) based on personal experiences (Prieto et al., 2022).

Learning analysis

In the metaverse, technologies like computing, databases, or AI play an important role in providing and analysing huge amounts of data (Yang et al., 2022). Through analysing immense amount of data, learner's performance, progress and achievement can be displayed. Which makes the learning easier for both providing and receiving parts of the education. For example, Classting AI is an online class community application that can help to analyze learners' learning achievements and provide visual and personalized analysis reports (Kye et al., 2021).

Learning authentication

Comparing to traditional virtual spaces, the metaverse offers open, shared and decentralized digital space. With that being said, learners' information and data should be highly secured against any privacy or security breach to provide secure virtual world. Technologies such as blockchain or NFT (non-fungible token) enable learners' creations or works to be authenticated and traced which aims to keep the metaverse world safe, persistent, and sustainable (Berg et al., 2019; Vidal-Tomás, 2022). Blockchain will ensure that all decentralized data, databases, and computers are totally reliable and that only inhabitants of the metaverse are the legitimate owners of everything in the virtual world.

Technologies for Improving Quality of Education

The use of metaverse platform where cutting-edge technologies like AR, VR, cloud computing and Artificial Intelligence (AI) deserves more inquisition.

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Computer-Assisted Learning

When it comes to practical teaching and high-quality learning materials in online settings, traditional learning that takes place in a classroom face serious challenges. However, the entrance of introduction of video conferencing devices for remote learning into our lives provide opportunities for interaction. Additionally, as the trend for remote learning increases day-by-day students do not want to miss out the chance of having hands-on experience in the industry due to this inevitable transition.

There are some issues associated with remote instruction by Human-Computer Interaction (HCI). Students, for example, have been known through a survey conducted by Barnes & Noble Education that they find it challenging to stay attentive for long durations of time because of multitasking, lack of social interactions and unforeseen interruptions (Chamola et al., 2023). They have more impaired learning efficacy because of live-streaming learning's prolonged timeframe, and they support lower collaboration/engagement between students and teachers in light of the shift of the learning environment from a community-based public classroom, which enjoys the support of multiple facilities provided by the universities, to a private location, with restricted and limited resources (Chamola et al., 2023).

Virtual Reality in Education

Virtual reality consists of five main components that can be listed as following: 3D viewpoint, closed-loop interaction, dynamic rendering, increased sensory feedback, and inside-out perspective. Due to the simple accessibility of many inexpensive Head-Mounted Displays (HMDs), greater computing power, and a range of uses, including STEM (science, technology, engineering, and mathematics) education, psychotherapy, and surgical procedures, VR has shown to be effective (Chamola et al., 2023).

However, there are some problems that we need to work on abolishing such as associating VR with games and entertainment, hence the main purpose of winning appears ahead of learning. Moreover, we can mention the psychological aspect and cost of the equipment as the additional obstacles before integration into the learning system.

Augmented Reality in Education

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An information layer of context is added to the user's perception of physical effort in augmented reality, a three-dimensional technology (Chamola et al., 2023).

Main reason behind the AR technology's popularity is that it can operate without the necessity of any special equipment or gear; it can be used with smartphones and tablets. Nevertheless, AR has its own challenges and limitations. Usability is a problem due to the fact that education settings are difficult for students. Tech issues are another problem.

Conclusions

Technical advancements of high-speed communication, computing, AI, and virtual technologies provide immense possibilities to develop the metaverse. Even though Gartner (2002) predicted that approximately 30% of people will spend 2h a day in the metaverse for different ends such as work, entertainment, education, and socialization by 2027 the metaverse is a very novel concept at least in educational sector. Once the educational sector embraces the opportunities and innovations that the metaverse brings to the table will change the game. It will support both students and teachers and it will definitely transform the way we learn. The use of visual imagery and active participation in the learning process has increased recently, and it also makes it easier for teachers to employ pedagogies like inverted classes and collaborative learning, encouraging flexibility and positive class dynamics (Kaddoura & Al Husseiny, 2023).

Consequently, there is no question about the potential of the metaverse, however; it just recently started to prove its worth in the educational sector and it has not reached its potential regardless of the subjects. With the development of the technology, we will see more concrete examples where the metaverse increases the efficiency of the lessons.

Resources

Kaddoura, S., & Al Husseiny, F. (2023). The rising trend of Metaverse in education: Challenges, opportunities, and ethical considerations. PeerJ Comput. Sci., 9, e1252. DOI: 10.7717/peerj-cs.1252

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Chamola, V., Hassija, V., Singh, A., Mittal, U., Pareek, R., Mangal, P., Devika, D., Mahmud, M., & Brown, D. (2023). Metaverse for Education: Developments, Challenges and Future Direction. Preprints 2023, 2023081872. https://doi.org/10.20944/preprints202308.1872.v1

Zhang, X., Chen, Y., Hu, L., & Wang, Y. (2022). The metaverse in education: Definition, framework, features, potential applications, challenges, and future research topics. Front. Psychol., 13, 1016300. DOI: 10.3389/fpsyg.2022.1016300

Rahman, K. R., Shitol, S. K., Islam, M. S., Iftekhar, K. T., & Saha, P. (2023). Use of Metaverse Technology in Education Domain. Journal Title, Volume(Issue), 79-86. DOI: 10.57019/jmv.1223704.

Ding, Y., Zhang, R., Zhang, S., Chen, S., Yan, X., Bian, Y., & Jiang, P. (2023). Under the Perspective of Technology Empowerment of Construction of Scenarios of Edu-Metaverse. In Proceedings of the 2022 3rd International Conference on Artificial Intelligence and Education (IC-ICAIE 2022) (pp. 150-157). Atlantis Press. DOI: 10.2991/978-94-6463-040-4_23.

Kang, Y. (2021). Metaverse framework and building block. J. Korea Inst. Inf. Commun. Eng., 25, 1263–1266. DOI: 10.6109/JKIICE.2021.25.9.1263

Jeon, J. H. (2021). A study on the principle of Metaverse composition with a focus on Roblox. Korean Assoc. Vis. Cult. 38, 257–279. doi: 10.21299/jovc.2021.38.10

Lee, H. J., & Hwang, Y. (2022). Technology-enhanced education through VR-making and Metaverse linking to foster teacher readiness and sustainable learning. Sustainability, 14(8), 4786. DOI: 10.3390/su14084786.

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