Metaverse-Based STEM Education for a Sustainable and Resilient Future

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Unit 9: Incorporating real-world applications and case-linked to STEM in the Metaverse

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Introduction

Metaverse has very recently became a term which we started use in different domains ranging from education to gaming. Due to the fact that the technology is immature as the term itself, there is no clear consensus in the academic community or in the industry regarding the future of this technology. Currently, the term is being used to refer to three dimensional (3D) virtual environments that features a hybrid world of real and imitational objects such as avatars and other forms of digital objects (Aloqaily et al., 2023). Thus, a physical world could exist within a virtual world to certain extent due to the limitations of the technology. Through the world of the metaverse, physical space can be animated within the cyberspace that gives users the chance to socialize, construct objects, and engage in transactions with one another using avatars.

In order to incorporate real life related actions, activities etc. into the metaverse universe three core requirements are required: cloning of tangible and intangible objects into the virtual environment, self-configuring and managing the virtual environment, and as the final one, maintaining trust and authenticity between virtual objects and transactions. Meeting these requirements requires remarkable amount of data collection, gathering, analysis, cloning and transmission. Although there have been a number of attempts to prototype metaverse applications and services, with the existing communication and networking infrastructure, it becomes difficult to realize the metaverse at full-scale (Aloqaily et al., 2023). However, we are getting closer to attaining these requirements with the breakthroughs in next-generation networks (NGN), especially the sixth generation (6G) which facilitates communication, data transmission and networking along with enhancing the metaverse services and applications. Minimum delay with high transmission capacity and accuracy is imperative for the synchronization and interaction of the metaverse experience. Thus, 6G is a fundamental component.

Object cloning from the physical world into the virtual world is about resembling the objects as accurate as possible. Digital twin (DT) is a paradigm that has emerged lately to enable the representation of a digital mirror for a physical entity (Aloqaily et al., 2023). The twins develop simultaneously and synchronously as long as the physical entity exists, and can evolve separately in the virtual world with the input from the real-time data gathering and the continuous advanced processing. For instance, during the lifetime of a person in the real-world, both the real person and the digital twin are synchronized both in the real and virtual worlds. But, after the person’s lifetime, its digital twin can continue to exist and evolve with the support

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of advanced Artificial Intelligence (AI) solutions (Aloqaily et al., 2023). This representation in the virtual world should not be limited to physical appearance, it should display some resemblance in terms of behaviours, actions and decision making. Reaching satisfactory level of resemblance can be achieved through utilization of AI.

DT for Real-World Metaverse

With the aim of providing services with high quality, metaverse employs mobile phones, cameras, helmets, and edge nodes and it relies on data collection, transmission, manipulation, and generation. Additionally, in order to construct real-world metaverse, a set of technological advancements is necessary such as next-generation networking and communications, ML, AI and DT.

DT is capable of enhancing the current services and provide new range of applications which might improve the integration of real world into the virtual world. In other words, far from entertainment services, a metaverse experience that duplicates the real world can provide advanced analysis of various situations that can occur in real life and enables in understanding the footprints of any system and making accurate daily choices (Aloqaily et al., 2023).

Hence, DT is imperative to visualize and construct the real physical aspects of the objects within the metaverse universe. Creating the digital clone of the real world inside the metaverse is feasible through real-time collected data. With this data, real features of the objects can be reproduced, realistic responses can be collected and analyzed. Building such an environment generates an opportunity to new sophisticated way interaction.

Real World Metaverse Framework Operation

The real-world metaverse is attainable with the involvement of the DT of every single entity, concept or operation within this 3D environment. Therefore, an extreme amount of data is highly needed in such a system, including Internet of Things (IoT) data and high-resolution videos. This collected data should be run by AI and ML-based processing methods to generate DT and visualize its 3D representation. In addition, the metaverse provides a flexible and natural way of interacting with the created objects by allowing the participants to use their real-life gestures such as grabbing, moving, and zooming (Aloqaily et al., 2023).

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For this goal, user gestures should be tracked with dedicated tools and approaches, hence extracting other types of data that have to be analysed. Various tasks involving data collection, transmissions, analysis, processing, and finally sharing the output should be performed with very high attention to the precision and delays for the sake of total synchronization.

Realization the of metaverse requires sound cooperation between technologies such as DT, XR, 6G and the blockchain. Once these technologies are provided, an interaction emerges:

- First of all, a DT of the various objects, operations and services should be generated. Different types of data should be collected from the real world and forwarded in real-time through the 6G network to the designated edge nodes. Once the data collected at the edge node, they should undergo a pre-processing phase for extracting and cleaning the useful data.
- Then participants send a request to join the metaverse which is received by the metaverse manager layer, the section where it is processed to extract the requested features for designing the 3D environment.
- The XR layer allows the participants to interact in a flexible and natural manner using dedicated tracking tools such as the handheld trackers or the sensors embedded in the XR headset.

Education and the Realisation of the Metaverse

In the recent years, especially with the outbreak of the pandemic, online education has become quite popular and prevalent. There is a radical shift from traditional classes to online education such as Massive Open Online Courses (MOOCs). Teaching-learning systems, whether is synchronous or asynchronous, are based on 2D web-based environments. These environments have limitations like the lack of immersion and full engagement, unlike traditional classroom teaching (Mitra, 2023).

Using 3D technologies instead of 2D ones will help us overcome these limitations and many others. The metaverse applications will be a sound tool for finding solutions about medical, climatic or political situations as they develop. Education and training are also important field where the metaverse and its applications can prove their worth.

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The potential of the metaverse can properly be harnessed to create immersive learning possibilities through an innovative blending of virtual reality and physical classrooms, laboratories, or corporate training rooms (Mitra, 2023).

Studies on Metaverse indicate that the same has been used in education to create new learning possibilities for the collaborative, creative, project, and problem-based learning (Araya & Avila, 2018). Additionally, it can also employ various types of learning methods like virtual, blended, collaborative, personalized and problem-based learning. The tools and technologies associated with metaverse can be able to provide huge pedagogical support to the learners and enable them to have immersive learning experiences (Mitra, 2023).

The utilisation of the metaverse and the various learning methods together with associated tools and technologies can enrich the experience as well as making it more attractive. Few innovative prepositions to take advantage of the potential of the metaverse in education is listed below:

1) *Effective professional training and development*

   An educational metaverse might involve schools, colleges, universities along with organizations that provide professional trainings which aim to equip learners with real-life knowledge and professional experiences that are not easy to obtain due to unavailability of necessary resources, costs or risks.

   Learners can take a part in diverse training and development programs such as hands-on laboratory internships without being concerned about time and space.

2) *Simulation potentials of the metaverse*

   If we think about the traditional lectures, it is not always possible to teach or train effectively through textual materials as everyone usually learns in different ways. On the other hand, in the metaverse, it is possible to engage the sense of sight, hearing and touch of the learners to create a realistic world that can address specific learning needs or styles of the learners.

   Metaverse is capable of simulating real-life boardrooms and workplaces through creating virtual boardrooms that can make the employee feel as if they are in the middle of face-

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to-face conversations. In contrast to video meetings, with the metaverse, virtual meetings can be more engaging and interesting. Simulation tools with 3D virtual and augmented reality technologies along with haptic technology can be utilized for the implementation (Mitra, 2023).

3) *Innovative mentoring platform for the teachers and trainers*

Metaverse can cover computer science and educational technology, hence it can be beneficial for teachers and trainers in order to get sound training from mentors and industry professionals on the latest application of metaverse tools and technologies in education.

Learning strategies need to be employed in innovative ways. For instance, traditional concept map can be modified to 3D to depict the objects dynamically and more realistically. This can immensely increase the efficiency of the learning activity as the complex concepts, processes and procedures can be visualized along with performing on-job scenarios and case studies on real-life applications as exercises.

4) *Personalized learning and assessments*

Learners' capabilities of learning differ from one to another due to various factors such as knowledge levels, the pace of learning, absorption powers, preferences, learning motivations and attitudes.

Through the constant support from mentors, tutors and peers the students find more opportunities to learn and improve their skills within this virtual environment. Artificial Intelligence (AI) and Machine Learning (ML) can play important roles here. AI can be used to create automated virtual learning experiences through NPCs or non-player characters (Diaz et al., 2020). A mentor/tutor might not be able to provide assistance all the time, however; an intelligent NPC can replace a mentor. They can act as a guide through responding to frequently asked questions, evaluating their performances and

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providing real-time feedback. Several AI assistances like facial recognition, sentiment analysis,
gesture and body language analysis like eye movement/blinking, head movement, and hand movement of the learners can be helpful to understand their attentions, comprehension perceptions, and brain retentions (Mitra, 2023).

5) *Entrepreneurship skill development*

In the conventional course, it is hard to realize or experience business ideas and make decisions as the costs might be quite high. Yet in the metaverse universe, a situation where the learners can experience it and make decisions can be generated. As the learners collect information and create virtual workrooms, they will be getting guidance from skilled entrepreneurs or NPCs. They can further interact with other users in the Metaverse associated with similar businesses or products on various related issues to have real-world experience.

Application of the Metaverse and Education

Even though both the literature and the applications on the metaverse are very limited, there are some applications that could give us some idea on how to utilize the metaverse both in the present and in the future.

In order to give examples, we will focus on four types of the metaverse which are augmented reality, lifelogging, mirror worlds and virtual worlds.

Augmented reality has been evaluated to be effective in learning material that is difficult to observe directly or explain in text, fields that require continuous practice and experience, and fields with high costs and high risk (Han & Lim, 2020). For instance, thanks to Cruscope's Virtuali-Tee's augmented reality T-shirt, students are able to examine the inside of the human body as they are in an anatomy lab. Hence, concrete objects are connected to the abstract visuals. Additionally, a research team in a hospital in Seoul developed a spinal surgery platform that applied augmented reality technology. This platform uses a real-time projection of a pedicle screw used for spinal fixation on a human body structure as an overlay graphic based on augmented reality (Park, 2021).

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Concerning the lifelogging, people resorts to smart devices to record their daily lives on the internet or smartphones. As a representative example, the Classting artificial intelligence (AI) system in Korea is an online class community application called an educational social networking service (SNS). In particular, Classting AI analyses students' learning achievements and provides customized learning by level in all subjects (Classiting, 2021).

The mirror world is a type of simulation of the external world that refers to an informationally enhanced virtual model or "reflection" of the real world (Smart, Cascio, & Paffendorf, 2007). This is a virtual world where the appearance, information, and structure of the real world are integrated into the metaverse universe as if reflected in a mirror. Examples to this type of metaverse can be involve "digital laboratories" and "virtual educational spaces". For the first one, users to convene to play games with people who are physically distant in order to perform meaningful tasks. David Baker's team at the University of Washington, which studies protein structure, has used this digital lab to have people fold protein amino acid chains. Through this game, where the protrusion structure matches well, and the player gets points and ranks up if they succeed, the protein structure is found for an AIDS (acquired immunodeficiency syndrome) treatment, and the achievement of 60,000 participants in 10 days was described in a journal publication (Khatib et al., 2011). The latter, virtual educational spaces, are representative example of the mirror world is video conferencing systems such as Zoom, Webex, Google Meet, and Teams. Gathertown is an online video conferencing platform that supports conversation and business in a virtual space. Among the features of the platform chatting, interworking with external links, and decorating spaces might be mentioned. The mirror world metaverse is a great option to show the real world exactly as if reflected in a mirror while expanding the learner's information in an efficient way.

Whereas virtual reality is a type of the metaverse that stimulates the inner world. This technology includes advanced 3D graphics, avatars, and instant communication tools. It is characterized as an internet-based 3D space where the users can express themselves simultaneously through avatars. The avatar representing the user explores the metaverse world with AI characters, communicates with other players, and achieves the goal. Zepeto and Roblox are examples of virtual reality. Zepeto is a 3D avatar-based interactive service that has recently appeared, and Roblox is a platform where anyone can create virtual reality and create games by themselves to enjoy with friends and engage in various creative experiences (Long, 2019). Zepeto, operated by Naver Z based in Korea, creates a 3D avatar using facial recognition

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technology. Additionally, the user can change skin color, feature, facial expression etc. as they wish. Upon creating the avatar, it is possible to text or send voice recordings in the game. These features allow the users to perform various activities, games, educational role-plays etc. For example, a teacher can select a classroom map, open a room, invite students, and interact with each other by voice or message on the classroom map (Snow Corp., 2021). Roblox, on the other hand, is a virtual reality platform introduced in 2006 that enables users to create one's own space and enjoy games in real-time. Lee and Han [17] explain that Roblox is a "second real world" in which the virtual currency "Robux" is used, and the economic ecosystem is completed. It is characterized by users being able to make games on their own in virtual reality using the Lego-shaped avatar or to enjoy games made by others.

Concluding Remarks

The metaverse develops more with the technology, hence it might be foreseen that the metaverse will become more than just an ecosystem that combines avatars and virtual interactions. It will rather become a cyberspace for content creation, virtual economy, social interactions as well as service provisioning that might impose an effect on the real world and objects. For instance, virtual social interactions in the metaverse are likely to influence a possible behaviour change among people in the real world.

This foreseen role of the metaverse is not possible to achieve without the integration of numerous technologies namely AI, DT, XR, 6G and blockchain. Creation of a metaverse universe through utilization of these technologies will enable us to lift the limitations of traditional way of teaching and learning. Metaverse technology can provide several solutions to the limitations of traditional methods while increasing student engagement, motivation and efficient learning with innovative combination of 3D visualization. Learners can find support anywhere and anytime.

The integration of virtual tools with the teaching/training tools like Blended learning, Mobile learning, Inverted or Flipped classrooms, and social networks can also help to develop a dynamic and interactive system (Diaz, Saldana, & Avila, 2020). A possible creation of innovative blended teaching-learning platform within the metaverse can connect universities, workspaces, research centers, and online user. This connection will enrich learning experiences among participants from both instructors' side and learners' side. The learners can also be engaged in

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activity-based, collaborative, problem and project-based learning where they have the scope to get mentorship and hands-on guidance from industry mentors too.

Consequently, metaverse might generate a lot of opportunities for learning and training as it can neglect the limitations of the real world such as infrastructure, time and costs and methods of the conventional teaching. While doing that it will integrate real world into the virtual world to enhance the experience of the learners. Surely, there is a long way to go, however; it will become more and more developed simultaneously with the technology and it will opens new doors for effective teaching.

Resources

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