Journal of Engineering Science and Technology
Vol. 20, No. 2 (2025) 380 - 403

LET'S IMMERSE IN METAVERSE: OVERVIEW, CHALLENGES, AND STUMETA FRAMEWORK FOR SUCCESSFUL IMPLEMENTATION

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Abstract

The Metaverse has the potential to fundamentally transform the interactive learning by offering novel, immersive, and interesting experiences for both students and teachers. The use of the Metaverse in education can help break down physical barriers and enhance immersive, communicative, and engaging learning by enabling remote participation from students in virtual classrooms that mimic some characteristics of the actual far, expensive or dangerous classroom. This article provides an in-depth study on the application of Metaverse in education, focusing on upcoming difficulties and directions. First, we provide a general review of the Metaverse, its significance as a complementary technology to digital transformation, and its implication in supporting the digital and societal needs of the generation Z. A review of current studies using four types of Metaverse in education follows that. The tracking of issues and worries is then done, along with offering remedies to overcome or lessen them. Finally, we propose StuMeta, a framework for integrating the metaverse into education that would help to overcome or mitigate regulatory, ethical, and religious concerns. Furthermore, this framework may encourage the use of metaverse experiences. Thus, the educational institution will be able to design personalized immersive learning experiences that take into account the specific needs of each student. These experiences are using a learner-centred approach that gives the student a sense of immersion in virtual worlds and the responsibility of self-control and experimentation in learning environments. Since this framework covers the link between the technical aspect and organizational needs, the beneficiaries of this study range from senior management and decision makers to lecturers and students in universities and schools.

Keywords: Augmented and virtual reality, Generation Z education, Metaverse, Metaverse Framework.

1. Introduction

Modern technologies have revolutionized daily tasks, including education, health, and utilities, with minimal human intervention. However, the Covid-19 pandemic has led to a shift in social interactions, with people becoming more cautious of physical contact and meetings. Daily life patterns have shifted to electronic transactions, with children continuing education from home and work cultures adapting to remote work. Academics affirm a significant change in educational pedagogy in the post-Covid-19 era, particularly due to the introduction of industry 4.0 tools and AI systems. Therefore, the most significant new trends in educational architecture are:

- **Distance education**: Due to the epidemic, this approach has been employed in several nations as a substitute to conventional schooling.
- **E-learning**: It blends classes with distant learning via contemporary interaction channels to impact learners swiftly with substantially little cost.
- Artificial Intelligence: This trend is escalating towards the adoption of artificial intelligence technology to improve interactive online learning and introducing personalized education tools that let learners swiftly acquire new skills.
- **Metaverse**: an imaginary vision of the future: avatars of people and creatures, glowing and floating, windows in the air with contents to process. The emergence of portals that take you to other worlds. It also involves the integration of a digital world where people can participate in virtual conferences despite their actual presence in different places of the world. With its ability to mix real and virtual worlds, the Metaverse has generated strong interest in various fields (such as tourism, gaming, education, entertainment, business, and healthcare) over the past decade. The Metaverse environment comprises of many types of expertise, for example, big data analysis [1], human interaction [2], AI [3], AR [4], VR [5],game design [6], digital twins [7], IoT [8], and block chain [9]. Hence, Metaverse is seen as an exciting, interactive technology contributing to the development of education that offers many opportunities for innovation and creativity.

It is clear that major technology companies are now marketing their various platforms, gadgets and products and competing to announce their use in various fields. Given the possibilities offered by the metaverse immersive worlds such as merging the real and virtual worlds and the ability to communicate, the metaverse is an ideal model for education [10]. However, for the optimal application of the metaverse in education, it requires studying the feasibility of the application and analysing the concerns and ethical considerations.

Therefore, there is a need to develop a framework whose inputs are the determinants that must be available in the educational environment from the competent bodies such as quality and academic accreditation and the programs specifications. These requirements must be available to ensure the achievement of educational outcomes that benefit from the enormous potential of immersion experiences in educational worlds and communication with peers in digital spaces. This framework also should seek to work on resolving organizational, cultural, or even religious challenges and concerns, in addition to achieving inclusiveness and

accessibility as the most prominent criteria for digital transformation in providing advanced educational experiences.

The contributions of this study can be divided into three parts, which can be summarized as follows:

- First part: Examining the idea of the Metaverse and how it fits into the present development as a subsequent step to the digital transformation. In addition, discusses the metaverse role from a psychological point of view in meeting the needs of the user according to Maslow's revised framework for human needs in the digital era. This section is important as an introduction for the reader to understand the relationship of the metaverse to meeting the psychological needs of the student in the digital age and in light of the digital transformation of governments and educational institutions to provide competitive digital educational experiences.
- Second part: Monitoring challenges and concerns arising from the usage of the Metaverse in education and offering a range of answers and solutions to each issue and challenge in order to solve or mitigate the risks of these concerns. This section is important to summarize the challenges, fears and concerns of applying the metaverse in education and thus consider it one of the guidelines and determinants of the framework that will be developed in the following third part of the study contributions.
- Third part: Proposing StuMeta, a framework that combines the determinants from the previous two sections, as well as requirements from relevant bodies for describing educational outcomes and addressing regulatory, ethical and religious concerns and considerations.

2. Literature Review

Artificial intelligence, virtual reality, and other technological advancements have made it feasible for new types of social and economic interactions to take place in virtual settings. Metaverse is a virtual ecosystem for communication and interaction. It is a word consisting of two parts, the first “meta” (beyond, or the most descriptive) and the second “Verse” (coined from “Universe”) and meaning (beyond the world). Metaverse is “the permanent, immersive mixed-reality world where people and objects can synchronously interact, collaborate, and live beyond the limitations of time and space, using avatars and the immersion-supporting devices, platforms, and infrastructures” [11].

Through the removal of physical restrictions and design limitations, this technology will unlock a portal to a metaphysical universe [12]. Figure 1 inspired by [13], depicts the metaverse as a completely immersive and interactive virtual environment that blurs the distinction between the real and digital worlds, might be seen as representing the next stage of digital transformation.

The new "Maslow's pyramid" [14] in Fig. 2 emphasizes the digital need of the tech generation while suggesting that the Metaverse can fulfil various human needs at different levels. For example, the metaverse can provide basic needs such as digital infrastructure and connectivity, psychological needs such as social networks and online communities, self-fulfilment needs such as career and skills development opportunities, and social necessities including connectivity and engagement in the online marketplace [15].

The contemporary Metaverse is built on Generation Z's societal ideal that online and offline personas are same [16]. In other words, the user can experience both real and virtual worlds in one Metaverse world instead of being separated in two different worlds. The Metaverse has already been incorporated into a few businesses and organizations' efforts such as employee training, online gatherings, and entertainment. Our contemporary lives are rapidly incorporating the Metaverse. Therefore, to fully utilize the Metaverse, it is required to thoroughly comprehend it [17].

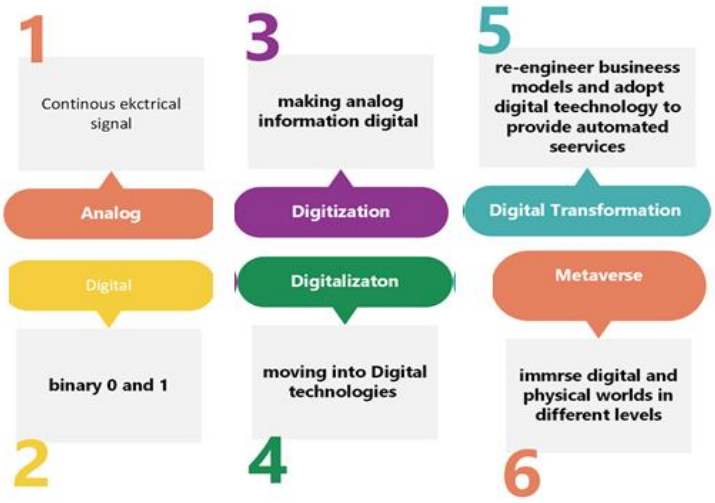

Fig. 1. Development from analog to Metaverse.

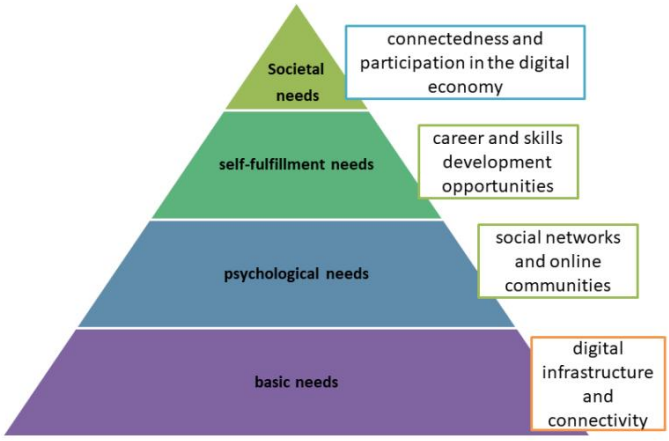

Fig. 2. Maslow's pyramid of digital needs.

Several research described Metaverse in general such as the study in [18]. For instance, metaverse fundamentals, security, and privacy of metaverse have been discussed in [19]. Teleworkers adopting metaverse have the intention to relocate to non-mega cities resulting in Shrink Residents Burden in Megacities [20]. Such

applications of the metaverse reflect its potential benefit to individuals and society as a whole through its contribution to serving employees, employers, and decision makers in reshaping the nature of work and its impact on society. Another great application of Metaverse technology is in the field of tourism by building virtual environments for historical and tourist attractions, potential tourists are enabled to immerse themselves in those virtual environments and experience historical events, space exploration, and natural phenomena such as volcanic eruptions [21]. This would enhance the tourism experience and make it more attractive and interactive for visitors.

Also, applying Metaverse technology can have significant marketing benefits [22]. For example, by creating immersive virtual environments, companies can use Metaverse technology to display products or services or allow customers to experience those products in more personalized virtual environments. Although these benefits, we stress the importance of enhancing individuals and companies' awareness to consider the potential risks and ethical implications of using Metaverse technology for marketing purposes, such as concerns related to privacy or the possibility of manipulation.

Many studies highlight the diverse range of applications for Metaverse technology that go beyond mere entertainment or tourism. It is clear that the integration of augmented reality and virtual reality has wide-ranging uses in medical education and training. For example, a summary of the application of Metaverse technology in medicine is presented in [23].

In addition, with Metaverse technology in gamification, there appears to be great potential in the prevention and management of obesity and non-communicable diseases. This shows that as metaverse development continues, it will be interesting to see how it can be further utilized to address health challenges and improve overall well-being [24]. an exciting development in the use of Metaverse in healthcare was discussed in [25]. For instance, by enabling virtual interactions between experts and terminal doctors, medical professionals can carry out a range of activities, including medical education, consultation, diagnosis and clinical research to increase patient access to healthcare in isolated or underdeveloped locations, as well as enhance collaboration and knowledge sharing among medical professionals [26].

Providing a flawless description of the metaverse and discussing its roles in education is an important step [27]. It is true that the metaverse's characteristics and its potential applications may not be known to most teachers. Another perspective of investigation is asking "if the Metaverse in education a blessing or a curse" [28]. Therefore, it is vital to increase educator's and researcher's motivations regarding the potential of the metaverse in education to help improve the learning outcomes especially during pandemics to ensure education continuity.

Zhang et al. [29] explore the potential of the metaverse in education, especially in the context of the COVID-19 pandemic. They concluded that the metaverse has been recognized as a trend of future education, but its potential in education is not well researched. The authors in [30] explores the potential of the metaverse in E-Learning systems to extend the students understanding. Another study discussed the effect of Metaverse world styles in conveying a game-full experience to users for metaverse-based education [31].

Interestingly, by leveraging game design principles, educators can create engaging and immersive learning experiences that motivate students to learn and explore. For example, in different level of education system such as elementary school, metaverse helps to analyse the metaverse experiences and attitudes from a constructivist perspective for learner-centred education to see how closely this virtual setting resembles the lives of elementary students [32]. As a conclusion, Metaverse as in Fig. 3 shows the following benefits when applying in education:

1. An immersive and interactive learning involvement for learners.
2. May enhance students' performance and engagement.
3. Personalized learning education, more fun, and entertaining.
4. Safe-Simulated environments for students to learn in.
5. Help for better learning outcomes attainment and comprehension.
6. Shrink costs for universities by excluding physical objects, materials and maintenance.
7. Prepare students better for the future and promote lifelong learning.

Fig. 3. Metaverse benefits in education.

3. Metaverse Four Types in Education

The methodology in which we tackle education might be reinvented by the metaverse, in both virtual and physical education [33]. While the technology is still in its early stages, there is already evidence of its potential in the lifelong learning strategies supporting the sustainable development goals. This could include simulations and scenarios that allow students to practice experiments and engage in skills development subjects in a safe and controlled environment, as well as access to resources and experts that may not be available locally. Moreover,

Metaverse might help prepare students for the future while also promoting their overall health and wellbeing.

The Metaverse can be categorized into four types as illustrated by Fig. 4 augmented reality [34], life-logging [35], mirror worlds [36], and virtual worlds [37]. Augmented reality can be understood as displaying additional digital information on the physical world [38], while life-logging involves recording and tracking personal data over a long period [39] by collecting and storing data about a person's daily life, including his or her thoughts, emotions, and experiences[40]. Life-logging may provide a way to reflect and analyse one's experiences and behaviours and thus is considered a mean of enhancing the inner world [41].

Mirror worlds are digital replicas of the physical world [42] through creating digital twins to collect real-time statistics in a geographically accurate way [43] which could provide valuable insights to decision makers. Reflecting on education, by linking the physical and digital worlds, the Metaverse could deliver a more immersive and interactive learning involvement for learners [44].

Virtual worlds are entirely digital environments that users can interact with. Each of these categories offers unique opportunities for education and learning, and as the technology continues to evolve, we may see even more specialized applications emerge. By understanding the different categories of the Metaverse and their potential applications, we can better explore the possibilities for using this technology in education.

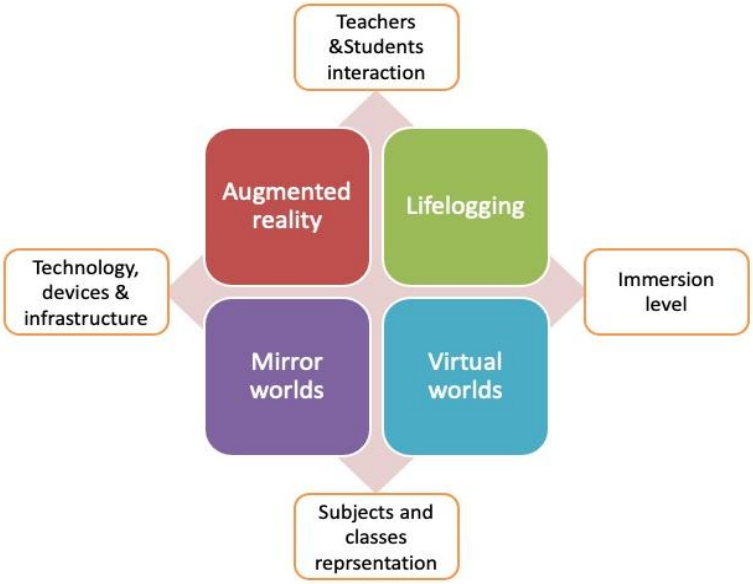

Fig. 4. Metaverse four types in education.

The latest studies on implementing the Metaverse four types in education are summarized in Table 1. Rather than highlighting the limitations of each study individually, the common issues and concerns of these studies are noted and will be discussed in the next section of this study (challenges) along with a recommended solution for each concern.

Table 1. Key findings of latest studies on Metaverse four types in education.

Metaverse Type	studies	Key Findings
Augmented Reality	[45]	The study indicated that previous methodologies lacked a framework to identify the types, technologies, and tags used that are appropriate for a specific usage situation and enable the creation of successful augmented reality experiences that achieve pre-defined goals.
	[46]	The study highlights the importance of security and privacy in virtual learning environments, with testing and auditing confirming the robustness of the metaverse against various cyber threats with a particular focus on accessibility and inclusive design, ensuring significant improvements in knowledge retention, student engagement, and user satisfaction.
	[47]	The use of AR to promote pedagogies that prioritize students is seen to provide a number of advantages and potential, including engaged educational experiences, improved enthusiasm and participation, and greater comprehension of difficult subjects.
	[48]	The most common educational approaches that make use of augmented reality include engaging instruction, instructional games and cooperative education.
	[49]	Using of augmented reality in education is examined by the authors from a number of perspectives, including the wide availability different technologies, educational activities, the authoring tools, suitable target groups and topics.
	[50]	The study's findings suggest that augmented reality education is preferable to traditional instruction, and that augmented reality interaction will greatly improve students' perceptions of and engagement with learning.
	[51]	To maximize the advantages of augmented reality for education, the study highlights some significant problems from earlier AR deployments.
	[52]	They go through how a person's exposure to multiple technologies and the resources available in their immediate area affect their decision on learning innovation.
Mirror worlds	[53]	They conclude that companies constantly adapt to harness the full potential of the metaverse driven by advances in XR, AR, MR and Mirror World technologies, in the areas of economic growth, innovative business opportunities, workforce training and customer engagement.
	[54]	Suggest there has to be a deeper connection between reality and virtuality than just reflecting real-world areas in the virtual world.
	[55]	Describe how Consumers through the metaverse may virtually touch, feel, and use products, while vendors can develop original content to build brand recognition and devoted fans.
	[56]	Argue for the necessity of establishing a 'contextual scenario' based on communication tasks. Mirror Worlds method would help students increase their actual communication skills largely.
	[57]	The authors go through the necessity for new medical students to become familiar with anatomical part pictures so they can apply imaging techniques in clinical settings using Augmented Reality Magic Mirror (AR MM).
	[7]	Discusses concepts and laws including "broken windows theory," "small-world phenomenon," "survivor bias," and "herd behaviour" for building a digital twin's model that would socially integrate both physical and virtual real-world things to the Metaverse.
Virtual worlds	[58]	Used the outer space mission simulator to examine student's opinion about astrosociology. The results showed students' support for virtual reality in space science education, and some comments about living in space and social interaction arose.
	[59]	Used bibliometric analysis to examine publications related to virtual worlds in education. They found that the most common keywords included e-learning, Second Life, and higher education.

	[60]	Provide an argument for regulations to maximize the educational value of virtual worlds and offer suggestions for developing instructional tasks in such settings, emphasizing interaction and awareness of existence

Table 1 (continue). Key findings of latest studies on Metaverse four types in education.

Metaverse Type	studies	Key Findings
	[61]	Employing the Scrum process, creating, building, and deployment of a virtual or metaverse world in a learning setting.
	[62]	The authors highlight the advantages and suitability of virtual world technologies for higher education's requirements in Covid-19 period and provide examples from universities globally that have applied virtual worlds and applications in their students' education post-pandemic.
	[63]	Advice on how to successfully integrate virtual worlds in distant learning from a pedagogical approach that focuses primarily on poor nations.
	[64]	emphasize certain important factors for teachers of social work to take into account When considering whether to employ virtual world technology.
	[65]	The application of MUVWs (multiuser virtual worlds) in medical schooling. The majority of goals for instruction were interpersonal skills and team building in hospitalization.
	[66]	Taxonomy identifies key areas of focus, including educational theory and the use of simulated environments for evaluation, grading, and accessibility.
	[67]	The student becomes an independent student who can accomplish their goals as they are fully involved in their studies and get exposure to the real world. Virtual reality does have certain drawbacks, too, such as limited eyesight, cyber illnesses, and a shortage of material.
	[68]	Discussing a delayed acceptance to use virtual reality in education due to the high cost of the equipment needed.
	[69]	Revealed that the study's four time periods-1992-2011, 2012-2016, 2017-2019, and 2020-2022-clearly separated the research on virtual reality-based education. There were proposed primary subjects for each time period. First, it is noted that "VR for learning and teaching" has gained importance recently. Second, it is noted that "VR in medical education" has been less prevalent in recent years. Third, "VR education platform" and "VR-based education in rehabilitation" issues continue to have some weight.
	[70]	Investigate how virtual reality (VR), are adopted by more and more educational institutions throughout the world to assist fulfil the demands of their varied student populations. Recent educational virtual reality applications have been employed in subjects including general, engineering, and health-related education.
Life-logging	[71]	Introduced" mixed reality lifelogging" to capture the experience of recording daily life from both real and virtual worlds. Limitation may include the legal aspects of live stream that may contradict privacy.
	[72]	The authors contend that the information gathered shows the necessity for more investigation into lifelogging for educational metaverse. This demonstrates the advantages of employing lifelogging technologies in virtual settings to improve students' learning outcomes.
	[73]	The authors suggest that a personalized experience in the virtual space, accompanied by analysis of the customer journey, is key to effective Metaverse marketing. Such technique might be useful for business education
	[74]	Goggle-like glasses that are worn while learning provide a virtual running friend called a "Ghostpacer" to accompany the student. To increase motivation and achieve the same results as jogging with a partner, it can be utilized to present a virtual companion that is tailored to the student's needs. Such method is adequate for sports education.

[75]	A complete examination of the progress made in egocentric data interpretation to date and suggests novel directions to help transition from visual lifelogging to storytelling.
[76]	Described the design, implementation, and process of a mobile-based system for looking back on old memories that uses a lifelogging system to let users store photos and related information in the cloud based on their location.

4. Challenges and Recommended Solutions

The possible advantages and disadvantages of metaverse can be determined by considering whether the metaverse in education is a blessing or an extra luxury [28]. On the one hand, the metaverse can help foster international collaboration and communication while also opening new possibilities for immersive and interesting learning experiences. On the other hand, it could also present issues including privacy and security worries, the need for more resources, and the need for teacher training. In Fig 5, concerns gathered from previous studies are represented, and the following details provide solutions for each issue to help academics and educators make wise decisions about how to utilize and apply metaverse in education environments.

4.1. Cost and resources

Metaverse technology can offer special benefits for some learners over traditional learning methods [77]. For example, it can be beneficial for children with learning difficulties or those who struggle in traditional classrooms. In terms of financial cost, the simulations that can be created in virtual metaverse environments may be less expensive than using traditional educational methods. For example, medical simulations can be used to save huge educational costs [78] compared to traditional education. The expense and resources required to install Metaverse technology can also be offset by potential long-term benefits such as the financial savings that can arise from requiring less classroom space and educational supplies.

Fig. 5. Challenges of Metaverse in education.

4.2. Mental health

Prolonged use of virtual environments can negatively impact metaverse users' mental health and well-being including identity crisis and aggressive behaviours [79]. Monitoring and providing support are crucial to ensure students do not overuse the Metaverse and take breaks and exercise regularly. Teaching students how to use the Metaverse responsibly and manage their mental health is essential, including incorporating mindfulness techniques, providing access to mental health services, and encouraging breaks and exercise.

4.3. Security and privacy

Distributed metaverse architecture is promising, but privacy and security issues remain. Education policy makers should consider the advantages of this approach, such as socialization, entertainment, and education. Developers, regulators, and users must work together to create a creative and safe metaverse, policies, legislations to save metaverse users [80], and focusing on ethical and safe innovation.

4.4. Maintaining student engagement and motivation

Enhancing learning outcomes and encouraging student engagement can be accomplished by incorporating game-like aspects into metaverse-based education. Hence, Student engagement can be positively affected through the use of metaverse technology [81]. Teachers may design a tailored learning experience that takes into consideration the particular needs and interests of each student by using a learner-centred approach. This approach may encourage a sense of ownership and accountability for learning, which may result in improved learning outcomes. Results indicated that due to it is immersive nature, Metaverse could serve as a resource to increase student participation in massive open online courses (MOOCs) to address high dropout rates [82].

4.5. Religious concerns

With the widespread adoption of the metaverse in many fields including education, some considerations have arisen regarding the adoption of the metaverse and concerns from a religious perspective. For example, there are some concerns that the religious application of some rituals will turn into a game that loses spirituality. One study suggests that while the metaverse can be used to teach Muslims about virtual Hajj, it cannot replace the physical actions prescribed in religious doctrine [83].

On the other hand, some may see an advantage in that it allows tele-religious experience that allows believers to visit and feel immersive experience of some religious sites that are geographically distant and expensive to reach with their other religious communities in a shared digital space [84]. Some see it as a catalyst for inclusive education, virtual pilgrimage, community building, facilitating religious events, and transcending borders. However, challenges such as preserving sanctity, preventing commercialization, ensuring authenticity, addressing ethical concerns, and navigating global regulatory compliance require careful consideration to fully harness the Metaverse's potential for religious tourism [85].

Therefore, by examining the potential tension between established religious beliefs and the modern Metaverse, the article in [86] proposes solutions and constraints to ensure that this virtual world harmoniously integrates religious values

into individual and social life. Consequently, the study in [87] provides important insights that can help educators, administrators, and policymakers in various ways in developing strategies, policies, and basic programs related to the adoption of the metaverse among students in terms of acceptance.

5. StuMeta Framework

By analysing the metaverse layers in [88], In order to construct a metaverse that aids students in achieving their learning goals, we propose StuMeta, a framework with ten key stages that are implemented progressively in accordance with the aims and objectives of the educational institution. In building the framework, we relied on integrating two methodologies: the first is the methodology inspired by Study [89] in developing the framework, which studies and analyses previous studies and extracts needs, guidelines and drivers, then reflects them in a theoretical framework.

The second methodology is in extracting academic needs from the perspectives of relevant departments and units, such as regulatory compliance, quality and academic accreditation, and academic ranking requirements. The Metaverse-based system is evaluated and improved based on the evaluation of students' academic performance and improvement suggestions from the constituents. With reference to enhancing learning outcomes, we take into account the role of linking the framework to the category of course learning outcomes according to the Education and Training Evaluation Commission (ETEC) in the Kingdom of Saudi Arabia (https://etec.gov.sa/en/service/accreditation/servicedocuments).

ETEC has divided the course learning outcomes that a student must achieve during their academic journey into three main categories: 1) Knowledge and understanding, 2) skills, 3) Values, autonomy, and responsibility. The impact of the StuMeta stages on the ETEC class when available is noted in the stage description below to illustrate the impact each phase has on achieving these skills. Figure 6 shows these stages, which are as follows:

i. **Preliminary stage**: At this stage, before starting, the vision, scope, programs and courses description, religious concerns, controls, and requirements for the educational system built on the metaverse are determined. This initial phase entails thinking about how the metaverse can enhance individual learning, foster collaboration and communication, increase student engagement with virtual environments, and provide opportunities for hands-on learning. It also includes studying and determining learning objectives, curricula, required infrastructure, and used technologies. It is also important not to neglect studying the ethical aspects of implementing the metaverse, such as dealing with potential privacy issues, as well as ensuring inclusivity and accessibility for all students before implementing it within the classroom. This stage is essential to determine the educational and experiential skills that students must acquire during the study of the various courses.
ii. **The physical stage**: With the upcoming development of the decentralized Internet and its applications, which will include the metaverse, it will constitute the largest sustained demand for computing in human history, which will require the network environment necessary to support the metaverse to be the starting point for this application [90]. During this stage, the necessary hardware and infrastructure are provided to support the virtual environment.

This includes CPUs and GPUs, servers, data centres, networking equipment, Labs for in-house development, services portals and other physical components that are necessary to ensure the metaverse operates smoothly and efficiently. Without a strong physical stage, the other stages would not function effectively. For beginner educational communities, the education platform VirBELA [91] can be used to build simulations of educational facilities.

iii. **The communication stage**: This stage facilitates communication and data transfer between users and systems within the metaverse. This stage provides the necessary infrastructure and protocols for users to communicate and interact with each other, as well as with the various digital assets available within the metaverse. The metaverse requires robust infrastructure such as ubiquitous connectivity, ultra-low latency, extremely high capacity and reliability, and strict security. In addition to full sensing of coverage to cover large numbers of teachers and students and give them real immersion in the educational experience, which is a huge challenge [92]. At this stage, attention must be paid to creating a verification and authentication system to handle sensitive data such as identity, password, and biometric information using a mutual authentication system using biometric information and elliptic curve encryption (ECC) [93] to provide secure communication between users and manage user identification data transparently in metaverse environments using block chain technology. As with the physical stage, the network stage is essential to ensure that metaverse components interact optimally in virtual environments without delay.

iv. **The platform stage**: This stage provides the software and tools necessary to develop and manage virtual environments within the system. This stage includes a variety of platforms, such as Unity or Unreal game engines, virtual world platforms, and social media platforms, which enable users to create, customize, and share their own virtual experiences. The platform stage is essential for enabling innovation and creativity within the metaverse. Emerging learning communities can use distance learning platforms that connect students with teachers like Brainly [94]. Google Arts & Culture [95] can be used for art and humanities subjects, while Labster [96] can be used to create interactive labs for science and technology education using augmented reality.

v. **Decentralization stage**: Responsible for distributing control among different participants rather than a single entity. Therefore, it enables greater security, privacy and control for users through a variety of methodologies, such as block chain, data analytics, AI, and RPA that can be used to record and manage academic works within the metaverse. By leveraging these technologies, educational institutions can use block chain to record and authenticate student certificates in a public ledger. In addition, students can have greater control over their data and academic achievements within the virtual environment. Finally, decentralization can help mitigate the risk of data breaches or other security issues, enhancing the overall safety and reliability of the Metaverse.

vi. **Spatial Computing stage**: Leveraging the capabilities of spatial computing helps to enhance the educational experience by providing students with more interactive learning environments. It also facilitates collaboration and communication between students and teachers within the metaverse. This phase provides appropriate geo-location technologies such as extended reality (XR) and geo-mapping, providing students and users with a real-time interactive

environment that makes interacting with virtual objects and worlds feel more natural and intuitive. During this stage, the interactive experimental environments will be linked to the learning outcomes that were identified in the first preliminary stage while determining the interaction outcomes.

vii. **The content stage**: This stage constitutes an important step towards enriching educational and entertaining content that helps students understand and improves educational outcomes. The content includes various digital assets and experiences available in educational virtual worlds and environments that are developed as an interactive learning environment. This stage includes things like 3D models, music, videos, and other multimedia content that help create a rich and immersive experience for students. With students from different cultures and languages, Mondly can be used to enhance language learning in an immersive virtual environment in real-life scenarios with native speakers [97]. The learning outcomes and its connection to the educational content are mapped and developed at this stage.

viii. **Human interface stage:** Since educational content will be developed in virtual worlds and there will be interaction between objects in those worlds, a set of interfaces must be provided to enable human interaction (students, teachers, administration) with the virtual world in several different ways, such as chatbots , digital twin, voice commands, motion detectors, smart watches, and glasses, smartphones and tablets. These integrated and interactive interfaces and channels will improve the interaction experience for students and allow them to explore educational content in the metaverse in an engaging and more natural way. The metaverse is a virtual space, so people with special needs can use their avatars to meet with everyone as if they were one of them, which achieves inclusiveness and ensures access for everyone.

ix. **The community stage**: The educational environment is a group of interconnected communities that interact with each other, starting from internal communities such as student communities, faculty, administrators and service providers to external communities such as the surrounding environment and the labour market. It is important that the educational metaverse works to enhance social interaction and cooperation among users through various social networks and communities within the virtual environment, where users can communicate, share their experiences, and collaborate on projects or assignments. This will help create a sense of belonging and engagement within the Metaverse and can also provide valuable networking opportunities for students and teachers. Communication and teamwork skills are developed at this stage.

x. **The management stage:**

   a. **The Assessment stage**: At this stage, appropriate interactive means are provided that enable teachers to evaluate students' work and assignments and provide immediate feedback and comments within the virtual educational environment. This layer can include different tools and technologies, such as automated rating systems, peer-review platforms, assessments, quizzes, or interactive assessments. The assessment layer ensures that students receive accurate and timely feedback on their work, which can help improve learning outcomes and overall academic performance. Assessment reports and corrective actions to achieve the desired educational outcomes are drawn up at this stage and these actions

are reflected during the continuous improvement cycle to develop curricula and content.

b. **The economy stage**: Educational communities within educational virtual worlds will need some buying and selling of educational or entertainment content or clothing and accessories for the avatars. In this stage, means of buying and selling, economic transactions, and interactions between students, institutions, and communities are provided in the virtual environment.
c. **The governance stage**: This stage includes many rules and regulations, policies, standards, and protocols that govern how the metaverse operates and how users interact within the virtual environment, which ensures ethical responsibilities to ensure that the metaverse is a safe, inclusive and fair place for all users. The management layer is accountable and can help prevent problems such as discrimination, exploitation or abuse.

To clarify the relation between the functions assigned to each stage of the framework and their treatment of the categories of challenges and problems that we extracted from previous studies and research, we also create a link mapping as in Table 2. In addition, the table clarifies the connection of this stage to associated unit, department, or organizational body. The table shows the interconnection between the various departments and units, including the technical sectors, to develop an integrated metaverse ecosystem in education. This interconnectedness is the essence of digital transformation, as it does not depend only on the technical sector to implement it, but rather it is everyone's responsibility.

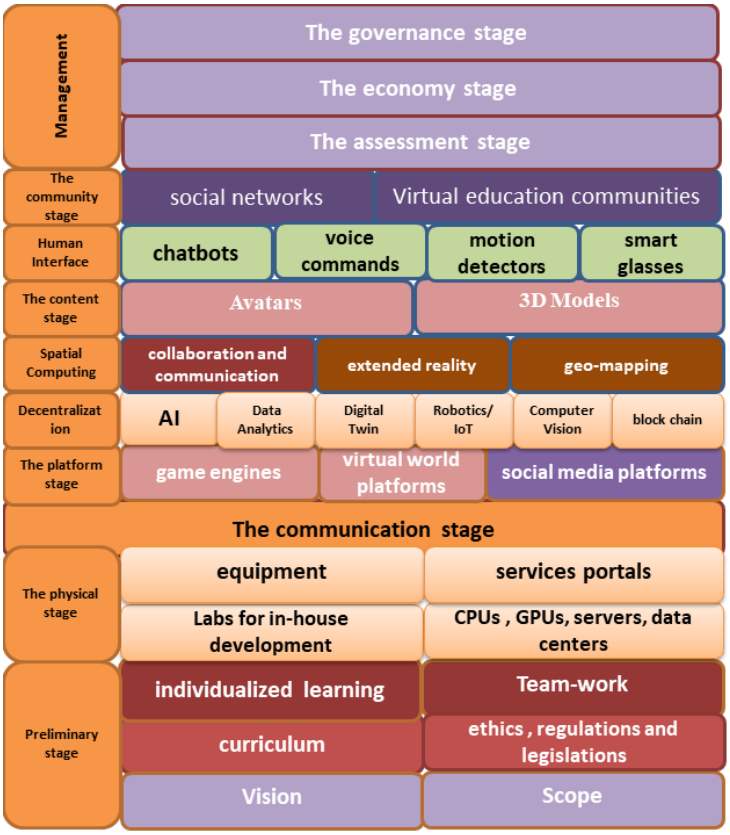

Fig. 6. Framework for the effective use of the Metaverse in education.

Table 2. Mapping of StuMeta framework stages and challenges categories.

#	phase	Associated Departments and units	Challenges class				
			Cost and resources	Mental health	Security and privacy	Maintaining student engagement and motivation	Religious concerns
1.	**Preliminary stage**	• Academic quality and accreditation • Academic departments • Curricula committees	√	√	√	√	√
2.	**The physical stage**	IT	√				
3.	**The communication stage**	infrastructure department	√				
4.	**The platform stage**	In house program		√		√	√

		development unit						
5.	**Decentralization stage**	Innovation department			√			
6.	**Spatial Computing stage**	IT				√		
7.	**The content stage**	Academic departments+ curriculum	√				√	
8.	**Human interface stage**	Programming Unit				√		
9.	**The community stage**	Students activities unit				√		
10.	**The Management Stage:** **a. the assessment**	• Exams unit • Academic quality and accreditation	√		√			
	b. The economy stage	Financial department	√					
	c. The governance stage	Top management	√	√	√		√	

6. Limitations

Essentially, Table 3 addresses the limitations or challenges that some educational institutions may face when adopting the framework proposed in this study. We aim to raise awareness about them in advance so that they take the necessary measures to prepare well before implementation. Table 3 also shows the proposed means to reduce or mitigate each limitation, which the educational institution can implement, in addition to any measures it may deem appropriate.

Table 3. Limitations/challenges and proposed solution.

Limitations	Description	Proposed solution
Overreliance on technology	Students can become too dependent on the virtual environment .Some students may lose social communication skills and direct interaction with others due to their heavy reliance on virtual environments.	Institutions must consider this during the preparation of programs and curricula and pay attention to include some courses that cover the development of some interactive, teamwork and problem-solving skills and an emphasis on interaction with extracurricular interactive activities.
Digital presence with Physical absence	Due to the virtual presence of students, some may intend to be absent and use various technical means to prove their presence in lectures	Develop strategies for teachers to interact with students randomly at different times during lecture time
Student engagement fades	Due to the nature of virtual reality and the lack of visual interaction, the desire for many students to interact with each	Include interactive activities and evaluation methods in the course specification.

	other or with the teacher may disappear.	
Class disparity	Some students may face class disparity in terms of financial purchasing power for products available in the economy stage, and this may lead to bullying.	These concerns can be resolved through proper legislation and regulations, setting clear limits and restrictions on the available products, or including methods to facilitate obtaining them, such as instalments.

7. Conclusion

By providing new immersive and engaging experiences for students and instructors, the metaverse has an opportunity to fundamentally change the way we teach. Using the metaverse in education can assist remove physical boundaries and improve immersive, communicative, and engaging learning by allowing students to participate in virtual classrooms from a distance while experiencing aspects of the real classroom. Additionally, the metaverse may alter classroom instruction, connect instructors and students virtually in common areas, and present fresh chances for invention, creativity, and self-confidence development.

However, because the infrastructure of the metaverse continues to grow, academics, educators, policymakers, and digital designers must take the lead in utilizing the metaverse potential for education. This study looks at how to meet the sociocultural and digital demands of students in the digital age. Then, after addressing the most important problems and challenges, we offer answers and solutions to alleviate any future worries. Finally, we proposed a ten-stage structure that serves as a framework for integrating the metaverse into education. The future work will test the framework using survey-based methods. We also aim to develop best practice learning standards to assess the level of application of the metaverse as an immersive experiential pedagogical method for achieving excellence in education. These standards are intended to guide policymakers and educators.

References

1. Siwach, G.; Haridas, A.; and Bunch, D. (2022). Inferencing big data with artificial intelligence & machine learning models in metaverse. *Proceedings of the* 2022 *International Conference on Smart Applications, Communications and Networking* (*SmartNets*), Palapye, Botswana.
2. Zhao, Y.; Jiang, J.; Chen, Y.; Liu, R.; Yang, Y.; Xue, X. and Chen, S. (2022). Metaverse: Perspectives from graphics, interactions and visualization. *Visual Informatics*, 6(1), 56-67.
3. Cheng, S.; Zhang, Y.; Li, X.; Yang, L.; Yuan, X. and Li, S.Z. (2022). Roadmap toward the metaverse: An AI perspective. *Innovation*, 3(5), 100293.
4. Gattullo, M.; Laviola, E.; Evangelista, A.; Fiorentino, M.; and Uva, A.E. (2022). Towards the evaluation of augmented reality in the metaverse: Information presentation modes. *Applied Sciences*, 12(24), 12600.
5. Anacona Ortiz, J.D.; Millán Rojas, E.E.; and Gómez Cano, C.A. (2022). Application of metaverse and virtual reality in education. *Metaverse*, 3(2), 13.
6. Shin, E.; and Kim, J.H. (2022). The metaverse and video games: Merging media to improve soft skills training. *Journal of Internet Computing and Services*, 23(1), 69-76.

7. Lv, Z.; Xie, S.; Li, Y.; Hossain, M.S.; and El Saddik, A. (2022). Building the metaverse by digital twins at all scales, state, relation. *Virtual Reality & Intelligent Hardware*, 4(6), 459-470.
8. Li, K.; Cui, Y.; Li, W.; Lv, T.; Yuan, X.; Li, S.; Ni, W.; Simsek, M.; and Dressler, F. (2023). When internet of things meets metaverse: Convergence of physical and cyber worlds. *IEEE Internet of Things Journal*, 10(5), 4148-4173.
9. Huynh-The, T.; Gadekallu, T.R.; Wang, W.; Yenduri, G.; Ranaweera, P.; Pham, Q.-V.; da-Costa, D.B.; and Liyanage, M. (2023). Blockchain for the metaverse: A review. *Future Generation Computer Systems*, 143, 401-419.
10. Jagatheesaperumal, S.K.; Ahmad, K.; Al-Fuqaha, A.; and Qadir, J. (2024). Advancing education through extended reality and internet of everything enabled metaverses: Applications, challenges, and open issues. *IEEE Transactions on Learning Technologies*, 17, 1120-1139.
11. Lee, U.-K.; and Kim, H. (2022). UTAUT in metaverse: An 'Ifland' case. *Journal of Theoretical and Applied Electronic Commerce Research*, 17(2), 613-635.
12. Doughan, Z.; Al Mubasher, H.; El Bizri, M.; and Haidar, A. (2022). The metaverse: A virtual world in the palm of your hand. *BAU Journal-Science and Technology*, 4(1).
13. Özdemir, A.; Vural, M.; Süleymanoğullari, M.; and Bayraktar, G. (2022). What do university students think about the metaverse? *Journal of Educational Technology and Online Learning*, 5(4), 952-962.
14. Yildiz, E.P. (2021). Academist perceptions on the use of web 2.0 tools through Maslow's needs hierarchy: A case study. *Education Quarterly Reviews*, 4(1) 173-188.
15. Kaddoura, S.; and Al Husseiny, F. (2023). The rising trend of Metaverse in education: Challenges, opportunities, and ethical considerations. *PeerJ Computer Science*, 9, e1252.
16. Park, S.-M.; and Kim, Y.-G. (2022). A metaverse: Taxonomy, components, applications, and open challenges. *IEEE Access*, 10, 4209-4251.
17. Lin, H.; Wan, S.; Gan, W.; Chen, J.; and Chao, H.-C. (2022). Metaverse in education: Vision, opportunities, and challenges. *Proceedings of the* 2022 *IEEE International Conference on Big Data* (*Big Data*), Osaka, Japan, 2857-2866.
18. Ng, D.T.K. (2022). What is the metaverse? Definitions, technologies and the community of inquiry. *Australasian Journal of Educational Technology*, 38(4), 190-205.
19. Wang, Y.; Su, Z.; Zhang, N.; Xing, R.; Liu, D.; Luan, T.H.; and Shen, X. (2023). A survey on metaverse: Fundamentals, security, and privacy. *IEEE Communications Surveys & Tutorials*, 25(1), 319-352.
20. Choi, H.-Y. (2022). Working in the metaverse: Does telework in a metaverse office have the potential to reduce population pressure in megacities? Evidence from young adults in Seoul, South Korea. *Sustainability*, 14(6), 3629.
21. Buhalis, D.; Leung, D.; and Lin, M. (2023). Metaverse as a disruptive technology revolutionising tourism management and marketing. *Tourism Management*, 97, 104724.

22. Dwivedi, Y.K. et al. (2023). Metaverse marketing: How the metaverse will shape the future of consumer research and practice. *Psychology & Marketing*, 40(4), 750-776.
23. Wu, T.-C.; and Ho, C.-T.B. (2023). A scoping review of metaverse in emergency medicine. *Australasian Emergency Care*, 26(1), 75-83.
24. Thomason, J. (2022). Metaverse, token economies, and non-communicable diseases. *Global Health Journal*, 6(3), 164-167.
25. Bansal, G.; Rajgopal, K.; Chamola, V.; Xiong, Z. and Niyato, D. (2022). Healthcare in metaverse: A survey on current metaverse applications in healthcare. *IEEE Access*, 10, 119914-119946.
26. Yang, D. et al. (2022). Expert consensus on the metaverse in medicine. *Clinical eHealth*, 5, 1-9.
27. Hwang, G.-J. and Chien, S.-Y. (2022). Definition, roles, and potential research issues of the metaverse in education: An artificial intelligence perspective. *Computers and Education*: *Artificial Intelligence*, 3, 100082.
28. Tlili, A. et al. (2022). Is Metaverse in education a blessing or a curse: A combined content and bibliometric analysis. *Smart Learning Environments*, 9(1), 24.
29. Zhang, X.; Chen, Y.; Hu, L.; and Wang, Y. (2022). The metaverse in education: Definition, framework, features, potential applications, challenges, and future research topics. *Frontiers in Psychology*, 13, 1016300.
30. Dahan, N.A.; Al-Razgan, M.; Al-Laith, A.; Alsoufi, M.A.; Al-Asaly, M.S.; and Alfakih, T. (2022). Metaverse framework: A case study on E-Learning Environment (ELEM). *Electronics*, 11(10), 1616.
31. Park, S.; and Kim, S. (2022). Identifying world types to deliver gameful experiences for sustainable learning in the metaverse. *Sustainability*, 14(3), 1361.
32. Suh, W.; and Ahn, S. (2022). Utilizing the metaverse for learner-centered constructivist education in the post-pandemic era: An analysis of elementary school students. *Journal of Intelligence*, 10(1), 17.
33. Yu, J.-E. (2022). Exploration of educational possibilities by four metaverse types in physical education. *Technologies*, 10(5), 104.
34. Elmqaddem, N. (2019). Augmented reality and virtual reality in education. Myth or reality? *International Journal of Emerging Technologies in Learning* (*iJET*), 14(03), 234-242.
35. Ksibi, A.; Alluhaidan, A.S.D.; Salhi, A.; and El-Rahman, S.A. (2021). Overview of lifelogging: Current challenges and advances. *IEEE Access*, 9, 62630-62641.
36. Hudson‐smith, A. (2022). Incoming metaverses: Digital mirrors for urban planning. *Urban Planning*, 7(2), 343-354.
37. Meepung, T.; and Kannikar, P. (2022). Metaverse; virtual world challenges and opportunities for digital business. *Journal of Economics, Business and Management*, 10(4), 277-282.
38. Kye, B.; Han, N.; Kim, E.; Park, Y.; and Jo, S. (2021). Educational applications of metaverse: Possibilities and limitations. *Journal of Educational Evaluation for Health Professions*, 18, 32.

39. Kim, M.-S.; and Noh, Y. (2022). A case study of the fashion brands marketing via metaverse. *The Journal of Transdisciplinary Studies*, 6(1), 57-76.
40. Gurrin, C.; Smeaton, A.F.; and Doherty, A.R. (2014). LifeLogging: Personal big data. *Foundations and Trends® in Information Retrieval*, 8(1), 1-125.
41. Mozumder, M.A.I.; Sheeraz, M.M.; Athar, A.; Aich, S.; and Kim, H.-C. (2022). Overview: Technology roadmap of the future trend of metaverse based on IoT, blockchain, AI technique, and medical domain metaverse activity. *Proceedings of the* 2022 24th *International Conference on Advanced Communication Technology* (*ICACT*), PyeongChang Kwangwoon_Do, Korea.
42. Sebastien, D.; Sebastien, O.; and Conruyt, N. (2018). Providing services through online immersive real-time mirror-worlds: The Immex Program for delivering services in another way at university. *Proceedings of the VRIC'*18: *Virtual Reality International Conference-Laval Virtual*, Laval France.
43. Che, W.; Lin, H.; and Hu, M. (2011). Reality-virtuality fusional campus environment: An online 3D platform based on OpenSimulator. *Geo-spatial Information Science*, 14(2), 144-149.
44. Rahman, K.R.; Shitol, S.K.; Islam, M.S.; Iftekhar, K.T.; And Saha, P. (2023). Use of metaverse technology in education domain. *Journal of Metaverse*, 3(1), 79-86.
45. Hidayat, R.; and Wardat, Y. (2024). A systematic review of augmented reality in science, technology, engineering and mathematics education. *Education and Information Technologies*, 29(8), 9257-9282.
46. Villegas-Ch, W.; García-Ortiz, J.; and Sánchez-Viteri, S. (2024). Educational advances in the metaverse: Boosting learning through virtual and augmented reality and artificial intelligence. *IEEE Access*, 12, 59093-59112.
47. Perifanou, M.; Economides, A.A.; and Nikou, S.A. (2022). Teachers' views on integrating augmented reality in education: needs, opportunities, challenges and recommendations. *Future Internet*, 15(1), 20.
48. Hanid, M.F.A.; Said, M.N.H.M.; and Yahaya, N. (2020). Learning strategies using augmented reality technology in education: Meta-analysis. *Universal Journal of Educational Research*, 8(5A), 51-56.
49. Nigam, S.; and C, P.S. (2022). Augmented reality in education system. *Journal for Research in Applied Science and Engineering Technology*, 10(7), 397-401.
50. Karuppathal, R. (2021). Impact of augmented reality education on students interactivity. *International Journal of Pharmaceutical Research*, 13(02), 690-698.
51. Garzón, J. (2021). An overview of twenty-five years of augmented reality in education. *Multimodal Technologies and Interaction*, 5(7), 37.
52. Lee, K. (2012). Augmented reality in education and training. *TechTrends*, 56(2), 13-21.
53. Yazıcı, A.M.; Özkan, A.; and Özkan, H. (2024). Meta: XR-AR-MR and mirror world technologies business impact of metaverse. *Journal of Metaverse*, 4(1), 21-32.
54. Pakanen, M.; Alavesa, P.; Arhippainen, L.; and Ojala, T. (2020). Stepping out of the classroom: Anticipated user experiences of web-based mirror world like virtual campus. *International Journal of Virtual and Personal Learning Environments*, 10(1), 1-23.

55. Jeong, H.; Yi, Y.; and Kim, D. (2022). An innovative e-commerce platform incorporating metaverse to live commerce. *International Journal of Innovative Computing, Information and Control*, 18(1), 221-229.
56. Ryu, S. (2022). An exploratory study on the possibility of metaverse-based Korean language subject design. *The Korean Association of General Education*, 16(2), 289-305.
57. Kugelmann, D. et al. (2018). An augmented reality magic mirror as additive teaching device for gross anatomy. *Annals of Anatomy-Anatomischer Anzeiger*, 215, 71-77.
58. Almurtadha, Y. (2024). Utilizing the metaverse in astrosociology: Examine students' perspectives of space science education. *International Journal of Advanced Computer Science and Applications*, 15(3), 720-727.
59. Battal, A.; and Taşdelen, A. (2023). The use of virtual worlds in the field of education: A bibliometric study. *Participatory Educational Research*, 10(1), 408-423.
60. Badilla-Quintana, M.G.; and Sandoval-Henríquez, F.J. (2021). Students' immersive experience in initial teacher training in a virtual world to promote sustainable education: Interactivity, presence, and flow. *Sustainability*, 13(22), 12780.
61. Díaz, J.E.M.; Saldaña, C.A.D.; and Ávila, C.A.R. (2020). Virtual world as a resource for hybrid education. *International Journal of Emerging Technologies in Learning* (*iJET*), 15(15), 94-109.
62. Attallah, B. (2020). Post COVID-19 higher education empowered by virtual worlds and applications. *Proceedings of the* 2020 *Seventh International Conference on Information Technology Trends* (*ITT*). Abu Dhabi, United Arab Emirates.
63. Krassmann, A.L.; Nunes, F.B.; Flach, J.M.; Tarouco, L.M.R.; and Bercht, M. (2021). A framework to prepare the application of virtual worlds in distance education in developing countries. *Universal Access in the Information Society*, 20(3), 451-463.
64. Martin, J. (2017). Virtual worlds and social work education. *Australian Social Work*, 70(2), 197-208.
65. Liaw, S.Y.; Carpio, G.A.C.; Lau, Y.; Tan, S.C.; Lim, W.S.; and Goh, P.S. (2018). Multiuser virtual worlds in healthcare education: A systematic review. *Nurse Education Today*, 65, 136-149.
66. Duncan, I.; Miller, A.; and Jiang, S. (2012). A taxonomy of virtual worlds usage in education. *British Journal of Educational Technology*, 43(6), 949-964.
67. An, M.Y.; Ko, K.A.; and Kang, E.J. (2020). Problems and directions of development through analysis of virtual reality-based education in Korea. *International Journal of Information and Education Technology*, 10(8), 552-556.
68. Roda-Segarra, J.; Mengual-Andrés, S.; and Martínez-Roig, R. (2022). Using virtual reality in education: A bibliometric analysis. *Campus Virtuales*, 11(1), 153-165.
69. Kim, D.; and Im, T. (2022). A systematic review of virtual reality-based education research using latent Dirichlet allocation: Focus on topic modeling technique. *Mobile Information Systems*, 2022(1), 1-17.

70. Kamińska, D. et al. (2019). Virtual reality and its applications in education: Survey. *Information*, 10(10), 318.
71. Aiordachioae, A.; and Vatavu, R.-D. (2024). Lifelogging in mixed reality. *Proceedings of the CHI EA'* 24: *CHI Conference on Human Factors in Computing Systems*, Honolulu HI, USA.
72. Alam, A.; and Mohanty, A. (2022). *Metaverse and posthuman animated avatars for teaching-learning process*: *Interperception in virtual universe for educational transformation*. In Panda, M.; Dehuri, S.; Patra, M.R.; Behera, P.K.; Tsihrintzis, G.A.; Cho, S.-B.; and Coello, C.A. (Eds.), *Innovations in Intelligent Computing and Communication*. Springer International Publishing.
73. Kang, H.-R. (2022). A case study on metaverse marketing of jewelry brand. *Journal of Digital Convergence*, 20(1), 285-291.
74. Huang, X.; Wild, F.; and Whitelock, D. (2021). Design dimensions for holographic intelligent agents: A comparative analysis. *Proceedings of the 1st International Workshop on Multimodal Artificial Intelligence in-Education*.
75. Bolaños, M.; Dimiccoli, M.; and Radeva, P. (2017). Toward storytelling from visual lifelogging: An overview. *IEEE Transactions on Human-Machine Systems*, 47(1), 1-16.
76. Sakib, M.N.; Rahman, M.M.; Mahmud, H. and Hasan, M.K. (2022). *Augmented reality-based lifelogging system for reminiscence*. In Hossain, S.; Hossain, M.S.; Kaiser, M.S.; Majumder, S.P.; and Ray, K. (Eds.), *Proceedings of International Conference on Fourth Industrial Revolution and Beyond* 2021. Springer Nature Singapore.
77. Chen, Z. (2022). Exploring the application scenarios and issues facing Metaverse technology in education. *Interactive Learning Environments*, 32(5), 1975-1987.
78. Shao, L.; Tang, W.; Zhang, Z.; and Chen, X. (2023). Medical metaverse: Technologies, applications, challenges and future. *Journal of Mechanics in Medicine and Biology*, 23(02), 2350028.
79. Kaur, N. (2023). *The effect of virtual and augmented reality on well-being*: *Perspectives in mental health education*. In Marriwala, N.K.; Dhingra, S.; Jain, S.; and Kumar, D. (Eds.), *Mobile Radio Communications and 5G Networks*. Springer Nature Singapore.
80. Camilleri, M.A. (2024). Metaverse applications in education: A systematic review and a cost-benefit analysis. *Interactive Technology and Smart Education*, 21(2), 245-269.
81. Muthmainnah; Al Yakin, A.; and Ibna Seraj, P.M. (2023). Impact of metaverse technology on student engagement and academic performance: The mediating role of learning motivation. *International Journal of Computations, Information and Manufacturing*, 3(1), 10-18.
82. Phutela, N.; and Grover, P. (2023). Metaverse as a platform for student engagement in MOOCs (massive open online courses). *Proceedings of the* 2023 8th *International Conference on Communication and Electronics Systems* (*ICCES*), Coimbatore, India.
83. Jubba, H.; Fernando, H.; Larasati, Y.G.; and Darus, M.R. (2024). Between reality and virtuality: A study of Muslim perceptions of metaverse hajj as a religious practice. *Khazanah Theologia*, 6(1), 13-26.

84. Fernandez, J. (2024). *The future of religion is virtual reality*: *Authenticating religious practice in the coming metaverse through an examination of religion in second life*. MSc dissertation, Department of Religious Studies, California State University, Long Beach.
85. Ahmad, M.; Akram, M.; and Ureeb, S. (2024). *Exploring the role of metaverse in promoting religious tourism*. In Singh, S. (Ed.), *Service innovations in tourism*: *Metaverse, Immersive Technologies, and Digital Twin*. IGI Global.
86. Awais, M.; Saleem, A.; and Amjad, M. (2024). The impacts of metaverse on religious concepts: An academic analysis. *Al-ISRA*, 3(1), 49-59.
87. Azhar, M.; Ali, R.; Naz, A.; and Sujood, S. (2024). Faith in metaverse: Understanding adoption intentions of metaverse amongst the Muslim students. *Journal of Islamic Marketing*.
88. Huynh-The, T.; Pham, Q.-V.; Pham, X.-Q.; Nguyen, T.T.; Han, Z.; and Kim, D.-S. (2023). Artificial intelligence for the metaverse: A survey. *Engineering Applications of Artificial Intelligence*, 117(Part A), 105581.
89. Roy, R.; Babakerkhell, M.D.; Mukherjee, S.; Pal, D.; and Funilkul, S. (2023). Development of a framework for metaverse in education: A systematic literature review approach. *IEEE Access*, 11, 57717-57734.
90. Cheng, S. (2023). *Basic Infrastructure of the Metaverse*. In Cheng, S. (Ed.), *Metaverse*: *Concept, content and context*. Springer Nature Switzerland.
91. Liang, J.; Li, G.; Zhang, F.; Fan, D.; and Luo, H. (2023). Benefits and challenges of the educational metaverse: Evidence from quantitative and qualitative data. *Journal of Educational Technology Development and Exchange*, 6(1), 71-91.
92. Tang, F.; Chen, X.; Zhao, M.; and Kato, N. (2023). The roadmap of communication and networking in 6G for the metaverse. *IEEE Wireless Communications*, 30(4), 72-81.
93. Ryu, J.; Son, S.; Lee, J.; Park, Y.; and Park, Y. (2022). Design of secure mutual authentication scheme for metaverse environments using blockchain. *IEEE Access*, 10, 98944-98958.
94. Al-Qoyyim, T.M.; Rahmatin, J.A.; Respasari, B.N.; Hijrotussulusi, H.; Zuhdi, M.; and Doyan, A. (2023). Physics learning using brainly platform during pandemic in Mataram city. *Journal of Science and Science Education*, 4(1), 11-15.
95. Melianti, A.; and Sugiarto, E. (2023). Pengembangan model pembelajaran inkuiri-seni berbasis Google art and culture untuk Siswa Sma. *Syntax Literate*: *Jurnal Ilmiah Indonesia*, 8(6), 4504-4521.
96. Erven H.; and Mosqueda, C. (2023). Effect of utilizing interactive virtual lab on students performance in physics. *International Journal of Advanced Research*, 11(05), 1718-1741.
97. Hajizadeh, S.; Rawdhan Salman, A.; and Ebadi, S. (2023). Evaluating language learning applications from EFL learners' perspectives: The case of Mondly. *International Journal of Technologies in Learning*, 31(1), 93-112.