Review Article

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Powered education based on Metaverse: Pre- and post-COVID comprehensive review

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Abstract: In recent years, an increasing interest has been in applying the Metaverse to create unique educational settings. This article reports a review of the literature on Metaverse and its application in higher educational settings to understand its definitive features, evolution from ideation to higher educational use cases, accessibility and affordability, ethical issues, current trends, and future research needs for effective and efficient Metaverse application in higher educational settings. A total of 58 publications between 1992 and 2022 retrieved from Google Scholar and other online portals were reviewed. The review was carried out using Nvivo software for qualitative data analysis to identify and extract the main themes from the reviewed papers, which were then organized thematically, discussed, and presented in the current article. The findings from this review provide an overview of the development of the Metaverse and its application in higher education from a pre-Covid and post-Covid perspective. It highlights the current state of research on applications of the Metaverse in higher education and the development of ten Metaversities funded by Meta, formerly Facebook. Furthermore, the article discusses the main concerns around adopting the Metaverse, which is mainly ethical issues such as data privacy, network security, netiquette, digital citizenship, copyright, and policies.

Keywords: Metaverse, educational technology, e-learning, digital transformation, education ecosystem

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1 Introduction

This review article opens with a discussion of the origins of the Metaverse as an idea birthed through science fiction in 1992. Its appearance in the academic literature on constructivist learning in 1995, its progression into a video game in 2003, and the development of the Metaverse roadmap, which introduced the four types of Metaverse: augmented reality (AR), virtual worlds (VWs), mirror worlds (MWs), and lifelogging (LL) in 2006 – all before the Covid-19 pandemic which led to a worldwide lockdown in 2020.

The article then discusses the impact of the Covid-19 pandemic, which led to global lockdowns, creating a huge market for virtual alternatives. Many schools, including higher educational institutions around the world, had to carry on with their academic calendar using various online video conferencing platforms. LL also peaked during this period as social life went virtual. This post-Covid era, alongside technological innovations such as the introduction of the meta-classroom, led to a significant surge in the use cases of the Metaverse globally across higher educational institutions. Subsequently, in 2021, Facebook rebranded as Meta and took on an initiative to build virtual twins of ten university campuses known as Metaversities, thereby taking the use case of the Metaverse in higher education to a new level. Despite the interesting prospects and developments, various challenges need to be overcome, particularly ethical issues that must be considered as the use of the Metaverse becomes more mainstream in higher education settings.

This work focuses on the main key strategies that can be implemented to enhance the future impact of the Metaverse on the smart education ecosystem and industries. The study thoroughly discusses and critically analyzes the

significant details of these strategies, providing insights into their potential to revolutionize education in the digital age. By highlighting the possibilities offered by the Metaverse, this work sheds light on the transformative role it can play in shaping the future of education.

Furthermore, this research presents a significant comparison between a Smart Education Ecosystem from a Metaverse perspective before and after the Covid era. This analysis allows for a comprehensive understanding of the profound changes and advancements that have occurred due to the pandemic. By examining the impact of Covid-19 on the integration of the Metaverse into the education sector, this work provides valuable insights into the potential opportunities and challenges that arise from such an evolution.

2 Backgrounds and methodology

Adopting a method earlier used by Lee and Hwang [1] and also by Sarıtaş and Topraklıkoğlu [2] for mapping the research field, the keywords "Metaverse", "virtual reality," and "higher education" were used as search terms on Google Scholar and other web portals to identify prominent publications on the subject. A total of 58 publications between 1992 and 2022 retrieved from Google Scholar and other online portals were reviewed. The review was carried out using Nvivo software for qualitative data analysis to identify and extract the main themes from the reviewed papers, which were then organized thematically, discussed, and presented in the current research article.

Though the Metaverse was largely popularized by an uptick in its use cases on the advent of Covid-19 in the year 2020, the Metaverse predates Covid-19. Neal Stephenson's 1992 cyberpunk science fiction book called Snow Crash introduced the Metaverse concept to most people [3–5]. Soon after, one of the first studies concerning learning in the Metaverse was published by Dr. Chris Dede of the Harvard Graduate School of Education on constructivist learning in the virtual environment Habitat. This caught the attention of academics [6]. Later, it was made accessible to the general public through the 2003 video game Second Life, developed by Linden Labs. In this game, people use digital avatars to freely enter a 3D environment that mirrored the actual world and engage in social interaction [7].

Since then, the Metaverse has manifested itself in numerous ways all around us, but interest in it has been rising globally in recent years [8,9]. The Acceleration Studies Foundation (ASF), a research group, revealed their Metaverse roadmap in 2006, which included AR, VWs, MWs, and LL [2].

Numerous definitions of the Metaverse were found in the literature. However, most of the previous research viewed it as a digital virtual environment where people may live, learn, or even work while creating avatar-based virtual identities. Students can visualize information and things in the virtual environment representing their knowledge, abilities, and concepts. Additionally, they can cooperate, engage, and co-create information in virtual reality (VR) [10]. According to Zhang et al. [7], a new virtual universe that has been built outside of the physical world is referred to as the "Metaverse," a compound word made up of the words "meta-" (beyond; transcending) and "verse" (the root of "universe," cosmos; the entire globe). Metaverse is also defined as an immersible 3D and virtual space that enables interaction among users, irrespective of place or time [11,12]. In Snow Crash, Stephenson portrayed the Metaverse as a 3D VR environment that readers might access using personal terminals and VR goggles. A digital environment called the Metaverse system (MS) allows users to interact and have immersive experiences. It can be characterized as an open, vastly scalable network of 3D real-time rendered VWs that an infinite number of users can concurrently access with a sensation of personal presence [13]. In the MS, VR is referred to as "the farthest extent from reality on the Reality-Virtuality Continuum" [3]. Users of VR headsets must focus entirely on virtual environments, so they separate themselves from physical reality [11,12].

While the Metaverse was already popular, especially among video game enthusiasts across university campuses, before 2019, the use of Metaverse in higher education took off in 2020 as a result of the Covid-19 pandemic.

3 The turnaround in VR after 2020

From the previous section, we see that the Metaverse had been in existence before Mark Zuckerberg, CEO of Facebook, re-introduced it on 28 of October 2021 as they rebranded as Meta. However, there has been a significant rise in the popularity of the Metaverse, in post-Covid times (Figure 1). This is mainly due to the Covid-19-inspired lockdowns that created an untact (non-face-to-face) society due to the Covid-19 pandemic [14].

People sought alternatives in the Metaverse as a result of the Covid-19 pandemic in 2020, which caused the human populace to live in a world where people were not face-to-face with one another [7]. The majority of traditional academic institutions and classes moved to online learning as a result of the Covid-19 pandemic [1]. The impact of Covid-19

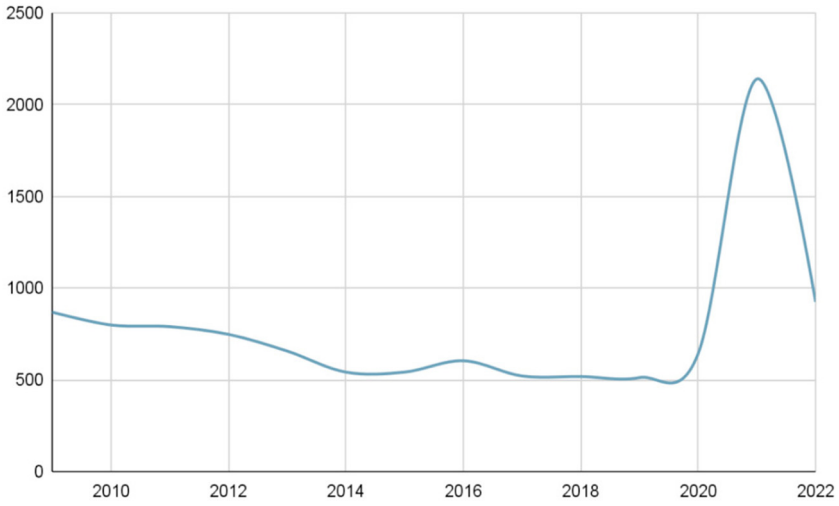

Figure 1: The growth of Metaverse in Google Scholar [10].

on the popularity of the Metaverse was so much that in a paper, interview participants said they understood the term "Metaverse" because of the Coronavirus [15]. A Web of Science search [10] revealed a consistent pattern indicating that the phrase "Metaverse" was not widely used before 2020. There were 15 (78.9%) articles from 2009 to 2019 among the 19 studies that were chosen; nevertheless, after the rebranding, the term's use increased. Four publications (21%) from 2020 to 2022 mentioned the word [10].

Figure 1 shows the development of how the term "Metaverse" was used in academic journals between 2009 and 2020 before the most significant social network business Facebook first announced its rebranding as Meta [10]. Since then, the phrase "Metaverse" has unexpectedly regained popularity [10]. As a result, 2021 came to be known as the first year of the Metaverse [7].

At least for users who can spend $299 or more on a VR headset, VR technology, such as headsets and haptic gloves, is more readily available now (in the post-Covid period) [16]. Several platforms for the Metaverse have been developed thus far (e.g., Second Life, Open Simulator, Minecraft, Fortnite, Roblox, Sandbox, and Decentraland). These platforms are drawing more users daily, reflected in the membership growth. Metaverse platforms offer additional advancements across the board as VR systems become more user-friendly and networked. It may be considerably easier to expand the adoption of VR devices and glasses once they have more comfortable designs suitable for extended use.

It's evident that interest in the Metaverse has been rising globally in recent years [8]. Suh and Ahn [9] identified four causes for this occurrence. First, the aesthetics have improved due to technology developments like 5G and 3D rendering, giving the Metaverse a more realistic feel. In addition, faster internet speeds have made it possible for users to enjoy the Metaverse immediately. Second, there is a higher need for non-face-to-face services as a result of the current Covid-19 pandemic. Third, the influence of the digitally native Generation Z has grown, leading to shifts in cultural consumption patterns. Fourth, users can now access the Metaverse whenever and wherever they choose, thanks to the widespread use of mobile devices and modifications in content kinds [17]. It is now possible to set up a virtual area comparable to reality and supply it at a lower cost because of the inventive development of communication technology, graphics, cloud computing, VR, and artificial intelligence (AI) technologies. If this was originally conceived as a "second" space notion, the recently created Metaverse might transform it into a "first" space concept that may even replace reality [18]. Lil Nas X's virtual concert on Roblox in November 2020, which attracted over 30 million spectators over the course of four performances, provides a more specific illustration [9,19].

4 Applications and types of the Metaverse in higher education

The post-Covid era has come with increased interest, better technology, new features, new applications, and redefinitions of the Metaverse. Specifically, the Metaverse has been described as consisting of a VW, an MW, LL, and AR. This is regarded as the early idea of the Metaverse under limited technology. Recently, differing Metaverse descriptions have been reported in the literature with the advancement of virtual technologies [9].

Metaverse is now being seen as the crossroads of key modern technologies, namely Extended Reality (XR) and Internet of Everything (IoE), where XR comprises VR, MW, and AR [20].

The Metaverse has become a VW to explore, where the user can interact in different ways through his avatar, exploring various contexts and even leading a double life [11]. For instance, as part of the Facebook rebranding, Mark Zuckerberg introduced a program to build Facebook as a "Metaverse": an embodied online world where people can present themselves, work, play, and socialize with avatars, often in the form of headsets or glasses [21,22]. The creator of Roblox, David Baszucki, similarly described the Metaverse as a setting that mixes high-fidelity communication with a brand-new method of storytelling that draws inspiration from mobile gaming and the entertainment business [18].

ASF's Metaverse roadmap has explained the types of Metaverse [14,23]. The first one is "Augmentation versus simulation" and the second one is "Intimate versus external," as shown in Figure 2a. This conceptualization of the Metaverse (Figure 2b) had also been described as an early idea of the Metaverse under limited technology [7]. The four types of Metaverse ((1) AR, (2) LL, (3) MWs, and (4) VR) are listed with details in Table 1. During the last period, the using of the mentioned four types of Metaverse has increased very quickly, and these types were developed to meet the requirements of the service markets. Also, it dissolves the distinctions between the many Metaverse subtypes. VR is fast

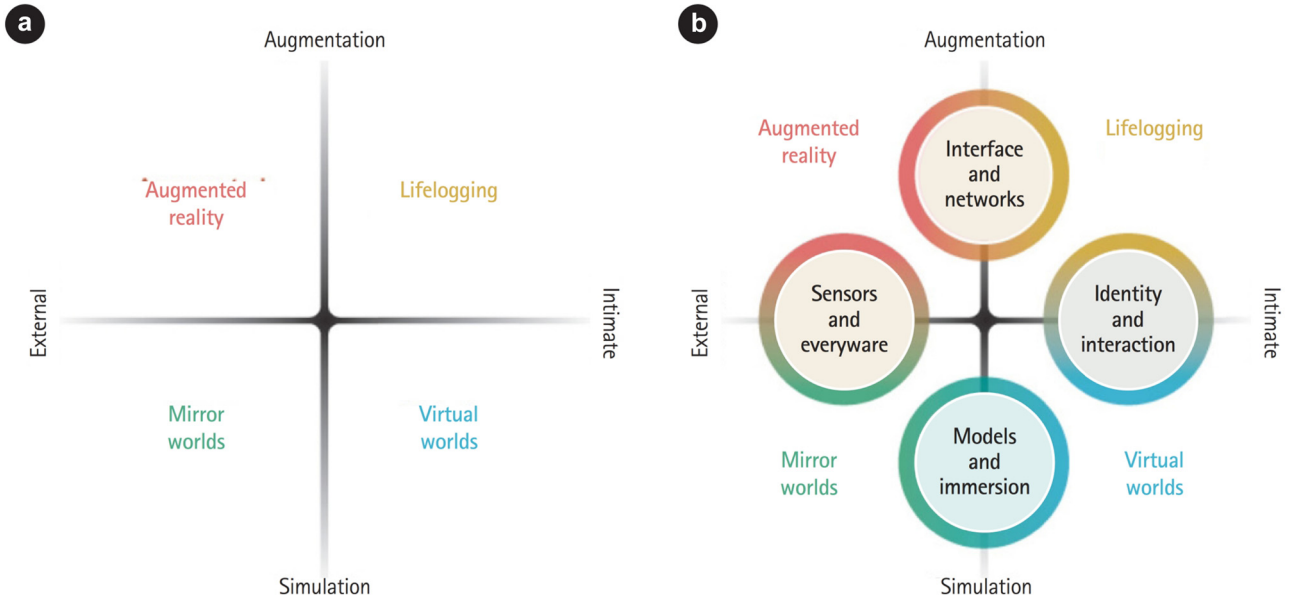

Figure 2: The diagram of four types of Metaverse [14,23].

Table 1: Four types of Metaverse [24]

	AR	LL	MW	VR
Definition	Building a smart environment by utilizing location-based technologies and networks	Technology to capture, store, and share everyday experiences and information about objects and people	It reflects the real world as it is, but integrates and provides external environment information	A VW built with digital data
Features	Building a smart environment using location-based technology and networks	Recording information about objects and people using augmented technology	Virtual maps and modelling using GPS technology	Based on interaction activities between avatars that reflect the user's ego
Application	Smartphones, vehicle head-up displays	Wearable devices, black boxes	Map-based services	Online multiplayer games
Use cases	Pokemon Go, Digital Textbook, Realistic Content	Facebook, Instagram, Apple Watch, Samsung Health, Nike Plus	Google Earth, Google Maps, Naver Maps, Airbnb	Second Life, Minecraft, Roblox, Zepeto

transforming previously thought of as being solely possible offline activities into industries including education, healthcare, fashion, and tourism [14].

4.1 AR

AR is a kind of augmentation of the external or real world. The term AR describes a kind of technology that makes use of a location-aware system and interface with additional and layered networked information on terrains we regularly explore to expand the physical world outside of a person [14,25]. Marker-based, see-through-based, and global positioning system (GPS)-based interfaces are the three main categories [14,26]. AR uses a mobile device's built-in GPS and Wi-Fi or can identify a marker in a quick response code to supplement existing information. Also, the real world and virtual visuals can be blended and seen in real-time with glasses or lenses. Learning content that is challenging to view directly or describe in words, disciplines that need regular practice and experience, and fields with high expenses and high risk have all been found to benefit from the use of AR [14,26]. With Cruscope's Virtuali-Tee, for instance, students can view the human body's interior as in an anatomy lab [14,27].

4.2 LL

LL is a kind of augmentation of the internal world. In the world of LL, people utilize smartphones or the Internet to record and share their daily lives. Twitter, Facebook, and Instagram are used for LL. New services in the medical industry now use biometric data stored on wearable technology. Some technology, like Nike Plus, connects sensors to record the amount of exercise or the location. The Classting AI system is an online class community application known as an educational social networking service. In particular, Classting AI evaluates students' academic progress and offers level-appropriate instruction in various topics [14,28].

4.3 MW

The term "MW" describes a kind of simulation of the outside world that is an informationally improved virtual representation or "reflection" of the outside world [14,25]. The appearance, content, as well as physical organization of the real world are converted to VR in the MW, which is a Metaverse. This is an "efficient expansion" of the real world, not quite a simulation [14,29].

MW Metaverse makes real-world existence simple and effective. Internet or mobile applications can be used to carry out real-world operations. "Virtual educational spaces" and "digital laboratories" are examples of representational MWs in education [14]. The spread of the Covid-19 epidemic led to an increase in the popularity of the MW Metaverse. Users interact and play games with remote players in the MW while doing important chores. The Foldit platform makes it possible for users to carry out scientific research through games. David Baker's team has utilized this virtual lab at the University of Washington to train participants in folding protein amino acid chains. This game led to the discovery of the protein structure for the treatment of AIDS (acquired immunodeficiency syndrome). This involved the participation of 60,000 people for 10 days [14,30].

This involves video conferencing tools such as Zoom, Team, Google Meet, and Webex. After the Covid-19 pandemic era, these video conferencing systems now act as the classroom in real time. Gathertown is a virtual meeting area for conversation and business that offers online video conferencing [14,31]. Its main functions include chatting, interacting with external networks, and designing (Figure 3). MW has enormous educational potential as a technique to effectively increase the amount of knowledge and skills needed for learning while accurately portraying the real world as it would appear in a mirror [14,29].

4.4 VR

Metaverse that simulates the inner world is called VR. This includes avatars, advanced 3D graphics, and instant messaging features. Users have the impression that it is entirely virtual. The opposite end of the spectrum from mixed reality and AR is frequently referred to as VR [14,32]. Based on how our eyes function, VR, on the other hand, causes us to perceive a flat image in three dimensions [14]. It is also regarded as an online 3D environment where a large number of users can log in simultaneously and interact by designing avatars to represent themselves [14,33]. The cultural context, people, setting, and institutions are all different in this VR Metaverse from what they are in the actual world.

From the foregoing, it can be seen that the Metaverse has essentially led to the opening up of new spaces for social communication. Roblox and Zepeto are VR Metaverses that provide people who could not go out due to Covid-19 with a new social space where they can meet and relax. The "Classroom Map"

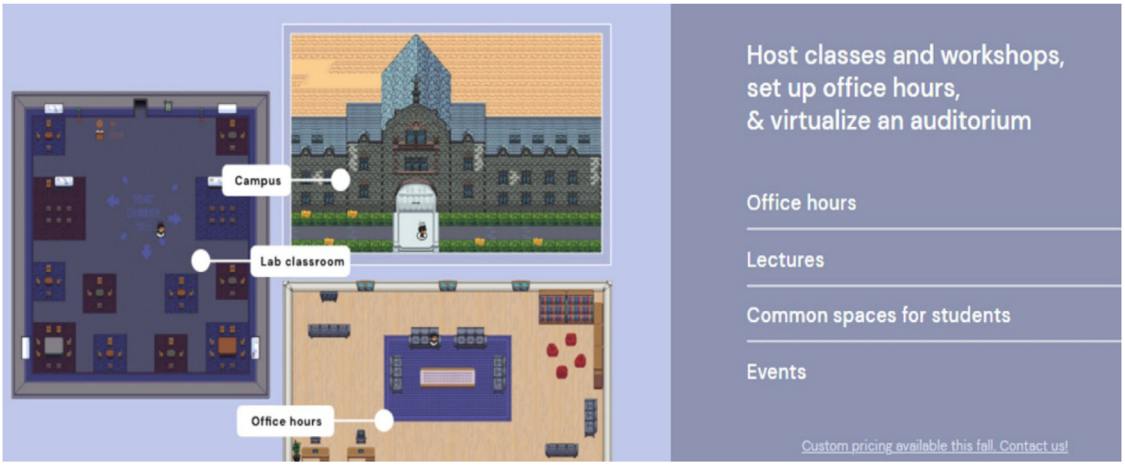

Figure 3: Classroom in Gathertown [14,31].

and other 3D maps in Zepeto became popular when schools were shut down due to Covid-19 lockdowns and students could not go to school physically. Rather than going to the actual classroom, the students went to the Zepeto classroom, where they met and communicated with their friends [14].

Roblox is a "second real world," with a fully developed economic system and the use of the virtual currency "Robux" [14,34]. Users can create their own VR games using the Lego-shaped avatar or play games created by others.

5 Enhancing metaverse accessibility in higher education

Dr. Chris Dede's article on constructivist learning in the VW habitat is one of the earliest articles about learning in the Metaverse [6]. Since then, Metaverse-based smart education has been applied in creating intuitive and interactive VR and 3D scenarios through which students learn various subjects, including languages, humanities, history, and geography, with personalized resources [34]. While active use of Metaverse remains rare in higher educational institutions, it is not so rare in certain fields and disciplines. There are indications that the majority of Metaverse research is carried out in higher education [35]. The Metaverse is gaining popularity as a virtual learning community. Extracurricular activities such as visiting virtual museums and laboratories and conducting social surveys take place in virtual communities [34].

As avatars, many researchers and practitioners entered the Metaverse for the first time in the virtual environment "Second Life," where they could interact with others, create assets, and buy and sell using a virtual currency based on the dollar [36]. Since many teachers and students havealready used the program Metaverse as instructional designers and educational technologists in the field of learning design and technology. So, they can be adapt very quickly with the nes development in this field. The use of the Metaverse is spreading gradually as more and more higher education institutions embrace the technology, but there are challenges with accessibility and affordability [36].

The accessibility and affordability problems are receiving attention, however, as big tech companies pour funds into Metaverse projects. For instance, with funding from Facebook, ten universities are building Metaversities, i.e., virtual versions of their university campuses. Similarly, VR technology in the form of headsets and haptic gloves is more readily accessible now – at least to consumers who can spend $299 or more on a VR headset [16]. A piece from EdSurge recently covered the ten universities called Metaversities collaborating with the business VictoryXR. Each of these universities will receive 50 headsets and a digital twin of their campus [37].

However, there are issues with talent, resources, and sustainability. Association for Educational Communications & Technology, an academic and professional organization, has a Graduate Student Assembly Metaverse group that actively promotes Metaverse in higher education, thereby contributing to improved accessibility [36]. According to Zhou [34], three main Metaverse applications can be used in higher education. The education of particular disciplines is the first. Students can learn a variety of courses, such as language, humanities, history, and geography, and access tailored resources with the aid of intuitive and engaging VR 3D scenarios. Virtual learning communities are the second. Students can engage in extensive extracurricular

activities, including visiting virtual museums and laboratories and completing sociological surveys in virtual communities in the community, which can act as a second classroom. Interdisciplinary education and occupational training make up the final application [34].

Students can carefully examine various historical and architectural locations thanks to Metaverse. Gaafar [38], for example, examined the potential of the Metaverse in architectural education by giving learners and instructors a chance to analyze heritage sites through virtual models of heritage buildings and their respective interactive 3D models. Gaafar concluded that being examined in a fully immersive experience through the interactive models of cultural heritages allows the learners to observe fine details [20].

A similar study [39] used a Metaverse environment with the Virbela platform's help to improve pre-service teachers' teaching abilities. In the experiment, pre-service teachers' virtual avatars were used to analyze microteaching for a group of them. The writers evaluated the teachers' skills in responding to questions and recommendations. By immersing teachers more fully in their profession while providing training and skill-improving activities for the students, such approaches assist teachers in honing their teaching abilities [20].

Díaz et al. [11] used a quasi-experimental study design in the classroom to examine whether students were content with the MS. Although Díaz et al.'s study concentrated on developing an educational strategy employing technological advances, it exclusively targeted mathematics instruction at the University of Cundinamarca. Therefore, the study was limited because it did not include other courses and might not apply to other fields [12]. Jagatheesaperumal et al. [20] identified five categories of Metaverse applications that are present in higher education (2022). The Meta classroom, military training, aviation, marine training, and industrial and sports training are some of these (Figure 4). XR, which combines AR, MW, and VR, and IoE are the main forces behind them.

Figure 4: Metaverse applications driven by XR and the internet of things [20].

5.1 Unleashing creative freedom

Though some people may not realize it yet, the Metaverse is more than just an online game. Users of online games are forced to do specific tasks in order to achieve the objectives established by the platform provider. However, without a predetermined objective, anything the user desires is ultimately conceivable in the Metaverse. Users can engage in a variety of activities in the real world, such as study, shopping, performances, exhibitions, and travel, depending on their ideal level of freedom. Additionally, they can share experiences like flying and space travel that are difficult to do in the real world due to physical limitations.

Instead of having to deal with the Metaverse puzzle, players can escape their hectic schedules and spend the day fishing, collecting fruit, or visiting a friend's island. Every decision is up to the user. Learning activities can be created to infinitely increase students' flexibility and experience by actively exploiting the Metaverse's properties. With their limitless autonomy, students will engage in self-directed learning that enables them to investigate their questions. They can take the initiative to find unique solutions while drawing on the concepts of innumerable others throughout time and space [14].

It can be recommend people to take advantage of virtualization to create new experiences with a high level of interaction. The Metaverse is also gaining popularity as a potential solution to the drawbacks of current 2D-based online and remote classes. Due to the intricate usage of numerous technologies, it can offer a unique experience value from the contemporary internet era. A unique experience that transcends space and time can also be created thanks to the Metaverse. The benefit of Metaverse-based education is that it allows for engagement on par with face-to-face instruction and allows for the usage of infinite space and data [14,24].

5.2 Ethical issues

Users of the Metaverse are potentially more dangerous than users of other online services and games due to the Metaverse ‘s high degree of freedom. The great level of freedom among users makes it impossible for the administrator to predict every user’s behavior. People feel less guilty about their crimes because of the virtual space and anonymity that are fundamental aspects of the Metaverse. There is a worry that new, more heinous, and technically advanced crimes may start to develop. The “I” taking part in the VW might look like an extension of reality and have a similar sense of self, but it might also take part as a self with a different appearance and point of view. The idea of an avatar can be understood by the word “sub-character” (extra character).

The degree of freedom in people’s identities is anticipated to steadily increase in a virtual space where one’s identity is completely concealed as life in which the VW and reality coexist becomes more widespread. In comparison to reality, it is only partially possible to recognize people. A higher level of anonymity in the Metaverse makes exposing illicit activities to them easier. The vast amounts of material created and shared by users all over the world cannot be individually restricted in a Metaverse that cherishes freedom. Therefore, it may become a lawless zone. Ethics education for cultivating citizenship in VW will be required. As the distinction between the virtual and the real world becomes blurred, users may experience confusion regarding their real identity, making it even more difficult to establish real-life relationships than it already is.

Jagatheesaperumal et al. [20] identified six key ethical concerns for Metaverse-based education: privacy, copyrights, digital citizenship, netiquette, network security, and acceptable use guidelines. All of these concerns are extremely important, particularly for using Metaverse in higher education.

5.3 Privacy, digital citizenship, and Netiquettes

The brain–computer interfaces and XR gadgets could give users access to Metaverse applications that can track their cognitive processes. They collect private user data and retain them in the blockchain for all time, despite using them to forecast customer behavior. The privacy rules of Metaverse applications should be studied and acknowledged to comprehend the repercussions of data breaches, data misuse, and personal data hacking.

Digital citizenship is the term used to describe how to behave responsibly and safely when online. It encourages the users to think critically and not to believe everything they see. It guarantees information security and connection to the intended parties. Users of the Metaverse are guaranteed by digital citizenship to behave and communicate responsibly. Kim and Choi [40] put forth a five-component digital citizenship model to guarantee online social involvement through appropriate activities. These models, driven by educators for the Metaverse, could offer learners trustworthy educational and training materials as a scale for digital citizenship. Digital manners are often referred to as “Netiquette,” where good communication is essential for asking questions and providing respectful and protective answers. Netiquette can be ensured in communication by using a polite greeting, asking specific questions, and providing a professional and appropriate conclusion. Being an ethical online citizen is essential in the Metaverse-based education programs being used in high schools, colleges, and businesses.

5.4 Acceptable use policies, network security, and copyrights

This refers to the regulations or guidelines that the owner, author, or manager of the educational resource or the system has implemented to limit how the resource may be used. It is an essential component of the security policy framework that grants new users access to the resources by having them sign the policy. To direct remote education, Brown [41] examined the historical and theoretical comprehension of the policies on educational materials.

Security is a major concern in using the Metaverse for higher educational purposes. Suppose head-mounted display devices are attacked. In that case, attackers can disorient users and overlay or manipulate the pictures in their field of vision as security concerns in immersive educational platforms rise. Casey et al. [42] demonstrated using VR systems for secretly managing people while submerged in a Metaverse environment. Attacks like these are known as “human joystick attacks.”

Managing digital rights on educational content against learning resource copyright infringement is difficult, given the broad emergence of multiple online educational platforms. A blockchain-enabled digital copyright management system ensures multimedia educational content sharing on both private and public blockchains [42]. It guarantees the privacy of instructional materials, making it a suitable option for Metaverse platforms as well. Blockchain can also be used to assert and defend intellectual property rights related to the

Figure 5: Ethical issues in Metaverse-based education [20].

ownership of resources utilized for technology transfer [43]. Other ethical issues of the Metaverse in education include addiction, identity, and social interaction [7] (Figure 5).

6 Current trends and future research

It has been fairly well established that XR and IoE will be crucial to educational services in the future Metaverse [20]. However, the latest technology with the most significant impact on the future of the Metaverse might be the rise of Chatbots such as ChatGPT, which is reported as stunning academics with its original essay-writing capabilities [44]. ChatGPT is an AI chatbot that understands and generates natural human language with remarkable sophistication, sensitivity, and usability from Elon Musk-founded OpenAI. Tesla CEO Elon Musk co-founded OpenAI in 2015 before parting ways in 2017 due to conflicts of interest between the organization and Tesla [45]. ChatGPT and similar technologies, such as Mid-journey, which comes with astounding AI prowess, pose severe ethical questions that call for more research to help us understand their potential impact on society. The advent of the Metaverse has led to smart education trends, simulating real teaching scenarios in virtual learning spaces, creating immersive teaching experiences with personalized learning, and promoting interdisciplinary studies in hitherto impracticable ways [34].

After reviewing various studies, several issues were identified as critical for future research into using Metaverse in higher education [7,46–48]. The review of the literature showed that there was no consensus on what kind of technologies should belong in the Metaverse world and on what educational theories, methodological, and pedagogical models should be used to conceptualize the Metaverse. Also, research is needed to establish the technological competencies, Metaverse rules, and principles needed for proper teaching and learning experiences, including assessment frameworks in the Metaverse. Little is known about the cognitive and non-cognitive impact of learning with the Metaverse, attitudes of school administrators, students, teachers, etc. [7].

It is important to evaluate how higher education students understand the Metaverse, their aspirations on the Metaverse, their interest in it, and the value they attach to their avatars in VR. Students' activity patterns, level of immersion in the Metaverse, and their positive and negative effects on students' learning activities should be studied [49–52]. Instructional designers and instructors interested in using the Metaverse for education need to properly understand the technical characteristics of each type of Metaverse and design classes to solve problems or perform projects collaboratively and creatively [53–55].

Two important objectives are to beachieved: the development of educational Metaverse platforms and regulatory frameworks, aimed to prevent or reduce the misuse of student data, in addition to educate them about how to use of AI chatbots such as ChatGPT in the correct way. Additionally, its needed to evaluate the studies about the collection data to support teaching and learning processes. Evaluation studies on data collection to support teaching and learning are also required [14].

7 Strategies and perspectives for enhancing the impact of the Metaverse

Integration of the Metaverse into smart education ecosystem has garnered considerable interest as an avenue to enhance learning experiences and outcomes. The exploration focused on key strategies and perspectives that could enhance the future impact of Metaverse technology in education. It also discussed insights from both pre and post-Covid eras, potential applications of the technology across industries, and concerns raised by students and teachers

about its implementation. Such discussions provide invaluable insight into using Metaverse capabilities for educational advancement while taking into account key implementation considerations.

Figure 6 provides an overview of key strategies to increase the future impact of Metaverse on smart education ecosystem. These strategies include collaborative partnerships, content creation, accessibility and inclusivity, professional development, research and evaluation, government support, community engagement, ethical considerations, parental involvement, and scalability and infrastructure. By using these strategies, educators can create immersive and interactive learning experiences tailored to individual student needs, foster collaboration and community spirit among colleagues, employ innovative assessment approaches, and increase learner engagement.

Table 2 provides an in-depth comparison between the Smart Education Ecosystem from a Metaverse perspective before and after the Covid era. The main aspects that are included in this table are as follows: access to education, location, interaction, collaboration, learning materials, personalization, flexibility, assessment, immersive learning experience, social interaction, teacher–student relationship, cost, and global collaboration. This table offers insight into the transformative effects of Metaverse on education as it illustrates its transformation of response from its intelligent education ecosystems in response to challenges posed by Covid era challenges.

Figure 7 provides solutions from a higher-dimensional world for the industrial Metaverse. It showcases potential uses of this space across data and analytics, advanced technologies, collaborative networks, simulation and optimization, and problem solving and innovation. By utilizing its potential applications, industries can streamline processes, increase productivity, and create immersive experiences for stakeholders by taking advantage of the Metaverse.

Figures 8 and 9 depict student and teacher concerns regarding the Metaverse before and after Covid became available, as seen by students, including privacy, accessibility, learning outcomes, digital divide, distraction, emotional well-being and technical issues. The concerns identified in Figures 8 and 9 provide the most important concerns of teachers and students about Metaverse before and after the Covid era. So, it can be concluded from these valuable figures that there are some points that are not solved until now and they need to be investigated deeply to find effective solutions.

Figure 6: The main key strategies that can be implemented to increase the future impact of the Metaverse on the smart education ecosystem.

Table 2: Comparison between a Smart Education Ecosystem from a Metaverse perspective before and after the Covid era

No.	Aspect	Before Covid era	After Covid era
1	Access to education	Limited access to quality education	Enhanced access to education for all
2	Location	Physical classrooms and campuses	Virtual classrooms and online learning platforms
3	Interaction	Limited interactivity between students	Increased interactivity through virtual tools
4	Collaboration	Limited opportunities for virtual collaboration	Enhanced opportunities for virtual collaboration
5	Learning materials	Traditional textbooks and physical resources	Digital learning materials and e-libraries
6	Personalization	Limited personalization of learning experience	Customized learning paths and adaptive learning
7	Flexibility	Fixed schedules and rigid learning structures	Flexible schedules and self-paced learning
8	Assessment	Traditional exams and tests	Diverse assessment methods and real-time feedback
9	Immersive learning experience	Limited exposure to immersive learning tools	Enhanced immersive experiences through VR/AR
10	Social interaction	Limited social interaction among students	Increased social interaction through virtual platforms
11	Teacher–student relationship	Physical presence and face-to-face interaction	Virtual presence and online communication
12	Cost	Traditional education expenses	Reduced costs for infrastructure and commuting
13	Global collaboration	Limited opportunities for global collaboration	Enhanced global collaboration and cultural exchange

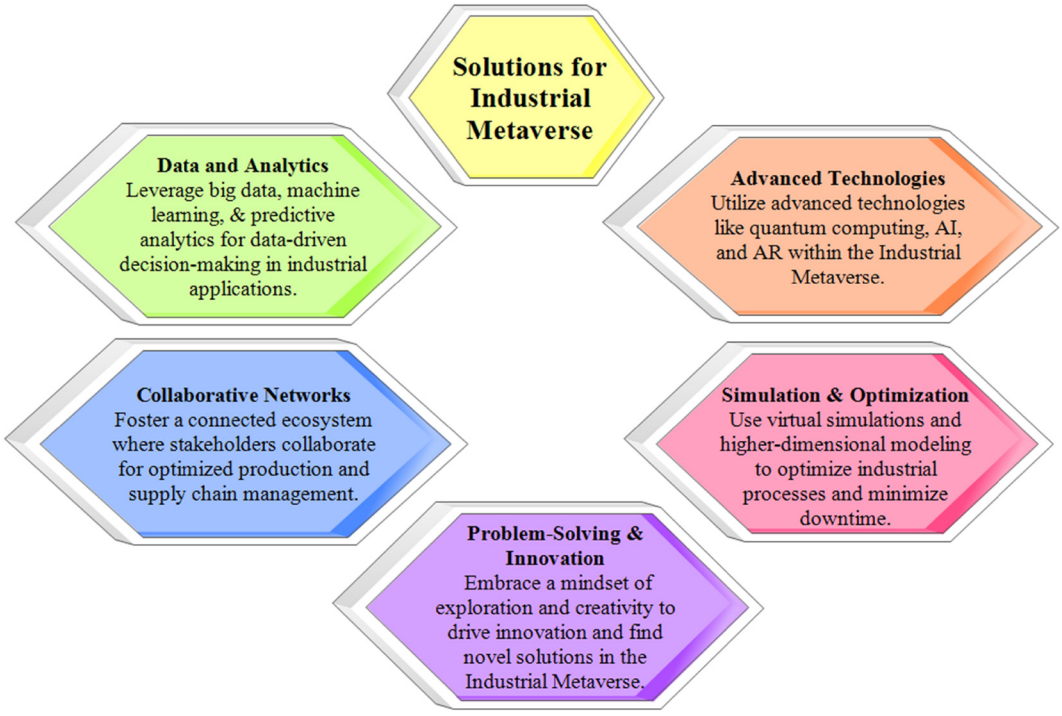

Figure 7: The solutions from a higher-dimensional world for industrial Metaverse.

8 Conclusions and remarks

The review of the literature indicated two definite eras in the development of the Metaverse: The pre-Covid era and the post-Covid era. The conceptualization of the Metaverse started during the pre-Covid era through a science fiction novel before getting the attention of academics and researchers who continued the development until it became a technological reality. However, real-life applications of the Metaverse in higher education took off after Covid-19 led to a lockdown, and the world sought virtual alternatives. In addition, other factors such as new technological advancements such as 5G, 3D renderings, AI, fast Internet, the coming of age of digital natives such as the Gen-Z children who were born into a fully digitalized world, the ubiquity of mobile devices, and the convergence of all these have conspired to make the Metaverse more mainstream in the post-Covid era.

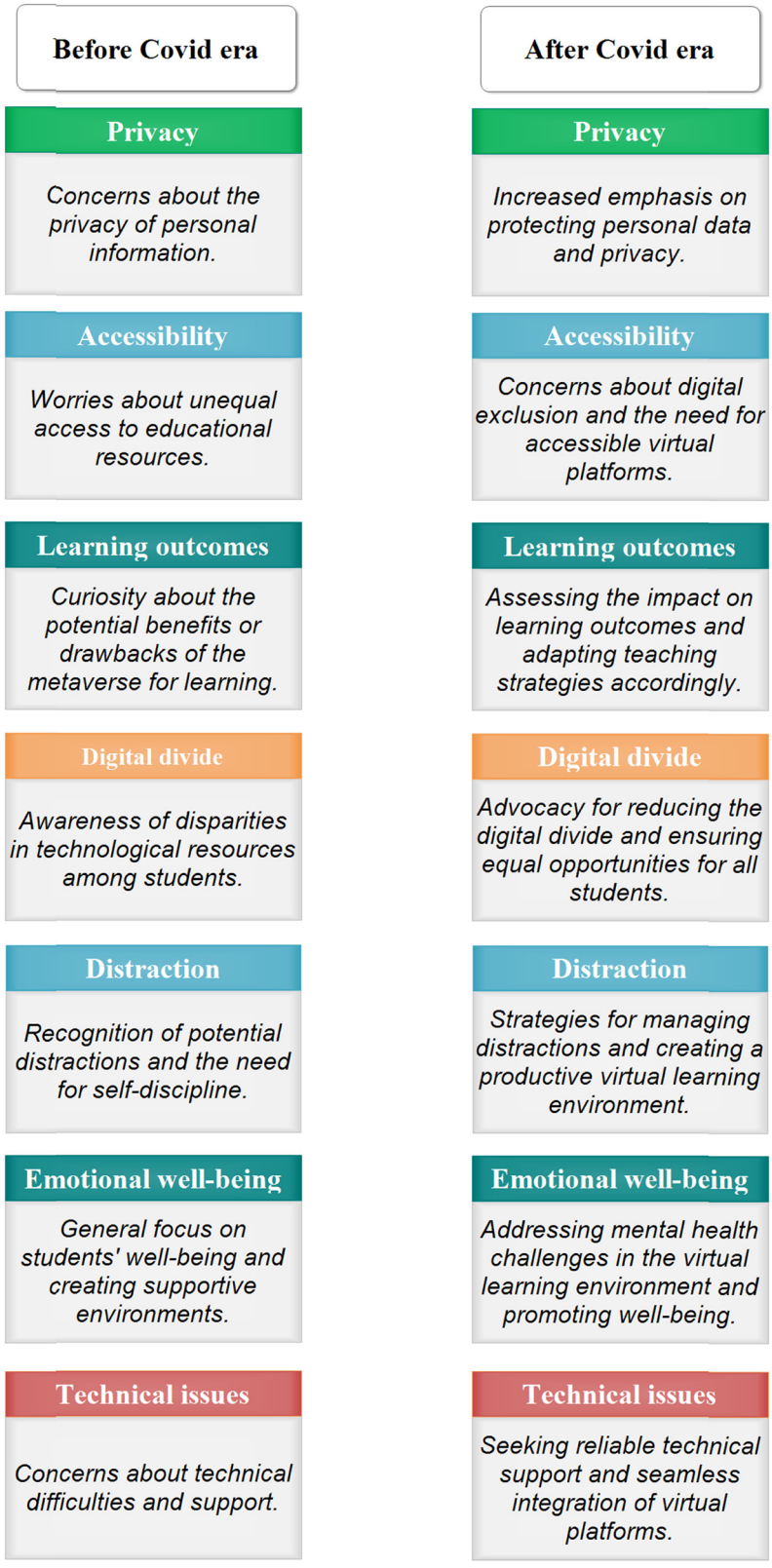

Figure 8: The student's concerns about the Metaverse before and after the Covid era.

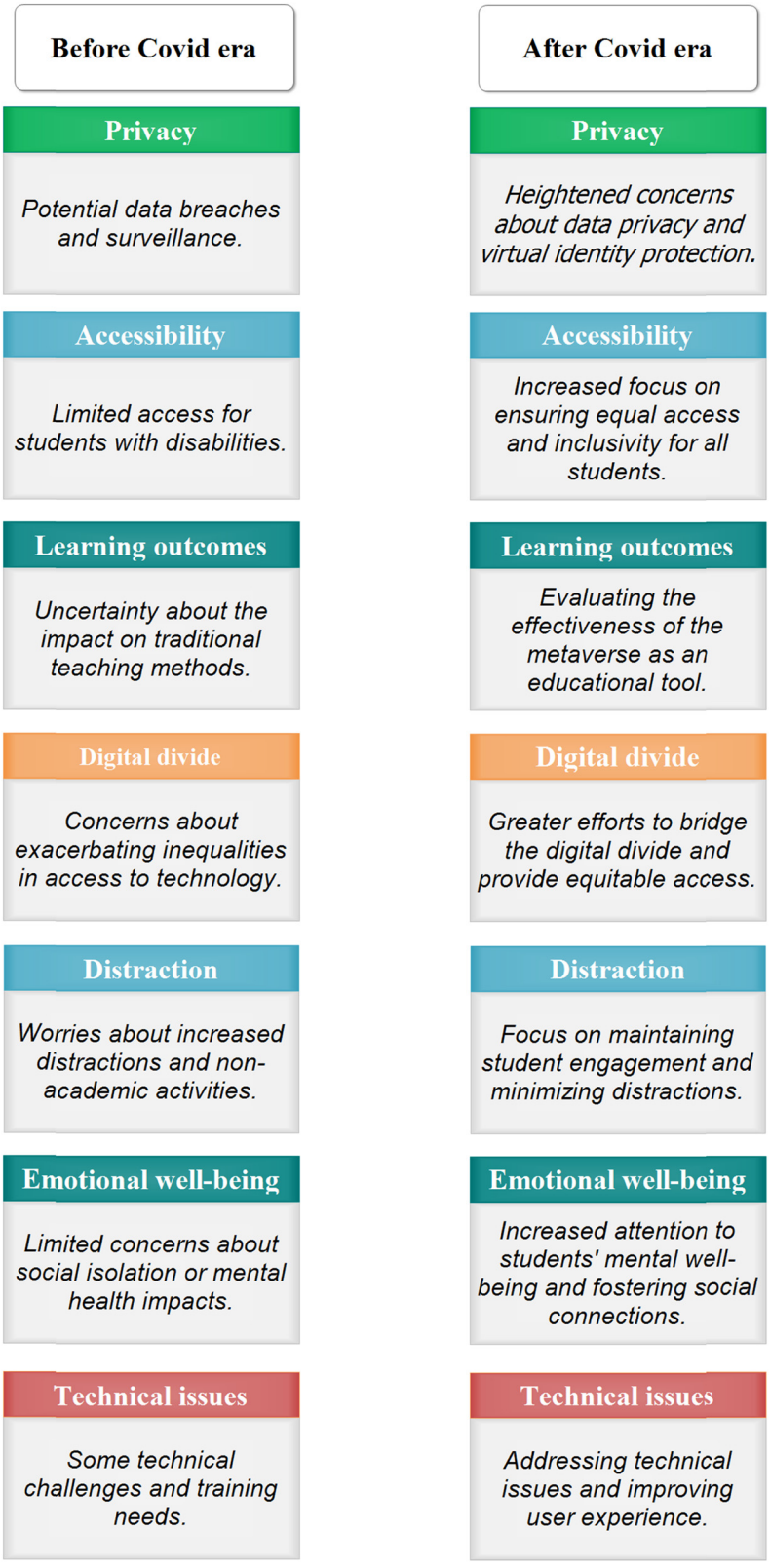

Figure 9: The teacher's concerns about Metaverse before and after the Covid era.

Perhaps one of the most notable developments that have impacted the adoption of a Metaverse in higher education comes from Facebook, which rebranded as Meta, positioned itself to take the lead in the further development of the Metaverse, and played a lead role in the development of ten Metaversities, i.e., virtual twins of ten university campuses. While challenges can inhibit the adoption of the Metaverse in higher education, the main concern as the Metaverse continues to gain prominence regards ethical issues such as data privacy, network security, copyright, netiquettes, digital citizenship, and policies.

9 Future works

Based on the conclusions of the current review article, it can be suggested that the following future works that have significant effects on education and industry applications should be investigated deeply.

9.1 Enhancing learning and training

Investigating how the Metaverse can enhance traditional learning and training methodologies has become essential in the post-Covid era. Through its immersive experiences, which offer engaging interactions between users, education institutions, and industry – as well as its potential transformation – education has the power to transform itself. Therefore, research must examine its specific ways in which it facilitates personalized and adaptive learning experiences for both students and employees, while analyzing its effects on knowledge retention, engagement, and skill development is imperative in both educational and professional contexts.

9.2 Virtual collaboration and remote work

With remote work and virtual collaboration becoming increasingly prevalent since Covid came into effect, investigating how the Metaverse facilitates these interactions is essential. By offering teams and organizations shared virtual spaces that foster collaboration, communication, and teamwork among remote workers and distributed teams, as well as offering tools that facilitate productivity, creativity, and innovation within remote work settings, this investigation can assess its effectiveness by measuring productivity, creativity, and innovation while identifying its advantages and limitations.

9.3 Simulations and experiential learning

The Metaverse can play an indispensable role in various fields like medicine, engineering, and business. Exploring this topic involves investigating how it provides realistic yet immersive environments for practical training, decision-making, and problem-solving in realistic yet immersive ways – including practical training that involves decision-making processes or problem-solving sessions with peers – decision-making exercises or problem-solving sessions with peers – plus its effects on developing practical skills or critical thinking abilities as critical measures of its worth in this research field.

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