Enhancing Engineering Education: Exploring the Educational Metaverse

Mirjana Maksimović

***Abstract*— The COVID-19 pandemic has had a variety of effects on traditional educational systems, and it has given online education an opportunity to grow. Hence, higher education institutions (HEIs) have realized the necessity to use advanced information and communication technologies (ICTs) to further increase students' online learning satisfaction and impact. A trend in future education has been hailed as the Metaverse, a 3D digital environment that combines the real and virtual worlds. As such, the Metaverse has the ability to provide engineering students with a setting and experiences that encourage and support teamwork, communication, subject matter expertise, creative thinking, and confidence. This paper, with a focus on engineering education, tries to comprehend the fundamental idea behind the Metaverse and to highlight the advantages that could be attained through its usage in engineering education as well as the difficulties involved in its acceptance in HEIs.**

***Index Terms*—5G, Metaverse, engineering education, HEI.**

I. Introduction

Higher education institutions (HEIs) have been forced to switch to online learning environments due to the COVID-19 pandemic. As a result, nowadays' educational systems and teaching methods increasingly include online learning. Online education can give students access to a wealth of learning resources, but it also prevents educators and students from interacting socially and emotionally which can have an impact on their satisfaction with the educational practices and their effectiveness [1].

A new era in education is believed to have begun with the development of the Metaverse as a new model for online education. "Meta" (means beyond; transcending) and "Verse" (derived from the term universe) are two words that together make up the term "Metaverse" [2]. Even though many people may not be familiar with the term "Metaverse," the ideas and technology that would be used to supplement or completely replace our everyday reality with a digitally enabled virtual environment are not new. The Metaverse is viewed as the next version of the Internet [3]; it is a 3D, global, networked, shared, immersive, lasting, and real-time online space where people may interact with one another and experience life in ways they are unable to in the real world.

The use of the Metaverse in education is known as the educational Metaverse. It establishes digital identities for educators, learners, decision-makers, and other interested parties, makes formal and informal learning environments accessible online, and enables educator-learner interaction in those environments. The educational Metaverse is a fully realized teaching and learning environment that requires innovative techniques to link the actual world with augmented reality (AR) and virtual reality (VR) experiences. It is based on emergent technologies including VR, AR, Mixed Reality (MR), Extended Reality (XR), 5G/6G, Artificial Intelligence (AI), blockchain, holography, Internet of Things (IoT), Digital Twins (DTs), etc. [1]. The current engineering education system needs to be reevaluated and revised in order to provide future engineers with a wide range of skills and competencies that will enable them to contribute to the development of innovative solutions to the engineering and societal problems of the 21st Century [4]. Learning engineering in an educational Metaverse could significantly improve future engineering education.

This paper attempts to summarize the role of Metaverse in engineering education, as well as to highlight the advances and challenges associated with educational Metaverse implementation in HEIs. As a result, the remainder of this paper is organized as follows. Following the introduction, the second section provides the concepts of the Metaverse. The educational Metaverse and the advantages and drawbacks of using it in engineering education are presented in the third section. The conclusions are given in the last section.

II. What is the Metaverse?

Metaverse, a 3D digital space with blurred boundaries between the virtual and real worlds, has drawn increasing attention as a result of technological advances in VR, AR, MR, AI, 5G/6G, holography, blockchain, IoT, DTs, etc. The specialties of these technologies are:

- VR and AR are two technologies that are thought to be crucial to the growth and development of the Metaverse. However, the three characteristics of the Metaverse - "shared," "persistent," and "de-centralized" - distinguish it significantly from traditional VR or AR. For displaying virtual content, an AR or VR system might be a component of the Metaverse; alternatively, the Metaverse could include both AR and VR components in addition to other necessary components [3]. VR technologies completely obstruct the outside world by creating an interactive, simulative virtual environment. Utilizing headsets, goggles, digital sensors, and

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haptic technology-enabled devices (e.g., gloves, vests, full-body tracking), users can explore this virtual world. AR technologies create a hybrid real-virtual world in which digital elements are augmented or superimposed on the real world [5]. Digital devices like smartphones with smart cameras, Google Glass, and heads-up displays in car windshields are examples of products that allow users to interact with the AR world. Real-time interaction and a virtual overlay of the real world are provided by MR. XR is a general term for technology that can alternate between VR and AR/MR [6].

- DTs are one of the main components of the Metaverse. The Metaverse is beneficial for building perfect duplicates of reality as well as for creating virtual worlds and experiences. DTs can provide realism to the digital environment because of their inbuilt features and functionalities [6]. The term "digital twin of a person" (DToP) refers to a virtual representation of an individual that can be present in multiple locations simultaneously in both digital and real-world settings, while the "digital twin of a customer" (DToC), learns to mimic and anticipate the behavior of customers (e.g., real people, fictional characters, social groups, or even machines) [7].
- Holographic projection has become more popular recently. Traditional VR and AR project a 3D world onto a user's viewable 2D surface. A holographic-like experience is provided by more sophisticated stereoscopic AR [8].
- AI technology is crucial for improving the effectiveness of Metaverse. Some of the examples are: using virtual teaching assistants, creating accurate avatars of users based on the analysis of 2D user images or 3D scans (DTs avatars will not only appear on computer screens but also be rendered as holograms that perform specific tasks), language processing for students from various geographical locations, learning outcome assessment, etc. [6].
- IoT technologies integration with AI and Machine Learning (ML) techniques enables connecting physical devices (e.g., VR headsets, haptic gloves, speakers, voice recognition) with the 3D virtual environment, and mapping real-time data to the digital world. For instance, IoT sensors that record each time users interact with a virtual object will allow users of haptic gloves to feel it. Effective data management, processing, and integration can be made possible by AI/ML technologies.
- Blockchain is the technology that enables the decentralization and protection of data in the Metaverse. Blockchain technology can be used to store in-game items, smart contracts, virtual real estate, nonfungible tokens (NFTs), etc., as well as to control data sharing and make data changes transparent. Blockchain can also assist Metaverse developers in identifying the origins of any incident that leaves servers exposed to risk or unsafe for users [6, 9-11].
- The 5G/6G - Metaverse relationship will be essential for the Metaverse to realize its full potential because high throughput, bounded latency, and extremely reliable networks are necessary to improve global access to the Metaverse. Reliable, secure, and low-latency communication is required for data transfer between AR/VR devices and the edge cloud. Because of its rate, range, reliability, latency, and other characteristics, 5G is currently the only wireless technology that has been demonstrated to achieve unrestricted connectivity. Around 2030, 6G is anticipated to offer an additional 100x speed increase over 5G, as well as additional latency and bandwidth gains. When 6G is fully implemented, users will be able to process large worlds on their mobile devices [8, 12].

Metaverse is acknowledged as the Internet's next generation, which is about to fundamentally alter how we interact with the outside world. According to Gartner [13], 30% of people will spend at least 2 hours per day in a Metaverse by 2027 for social media, work, education, shopping, and/or entertainment. By 2027, the size of the global Metaverse market is anticipated to grow at a compound annual growth rate (CAGR) of 47.2%, reaching USD 426.9 billion. In 2022, the market for the Metaverse was estimated to be worth USD 61.8 billion [14].

Metaverse joins users from all over the world in a single reality that replicates all facets of the natural world in an open, unrestricted artificial environment. Users can access the Metaverse from any internet-connected device (e.g., smartphones, tablets, desktops, XR headsets).

Since the Metaverse is still in its infancy, neither academia nor business have established a consensus on how it should be built. The author of [15] proposed seven-layer Metaverse architecture. It is composed of the following layers, arranged from bottom to top [11, 15, 16]:

1. The infrastructure layer or the Internet layer - enables connections between users, their devices, and the online world. Connective technologies such as 4G/5G/6G, and WiFi, and increasingly powerful and tinier hardware are part of this layer. All users in the Metaverse can have seamless, value-based experiences thanks to a strong infrastructure.
2. Human interface layer - includes physical-to-digital and digital-to-physical translators (e.g., VR headsets, haptics, AR glasses, 3D printers and scanners, biosensors, neural chips, virtual assistants, smart/voice user interfaces (VUI)) to help users understand the digital world and give it a natural feel.
3. Decentralization layer – since the essential component

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of the Metaverse is distributed computing, blockchain technology is a key component of this layer because it supports decentralized infrastructure and manages queries. It is important to highlight that a single entity can never have complete control over the Metaverse.

4. Spatial computing layer - provides assistance for a hybrid type of computation that blurs the boundaries between the physical and digital worlds. It includes 3D engines (for displaying geometry and animation), AR/VR/XR spatial mapping, integration of sensor data, and user interfaces.
5. Creator economy layer – contains all of the technology used by the creators to produce digital assets and experiences for end-users.
6. Discovery layer - contains the necessary data, such as relevant content, live streams, promotional emails and messages, and notifications that are broadcasted or informed by the marketing departments of the creators. This layer enables customers to learn about new platforms via app stores, search engines, and rating websites.
7. Experience layer – the physically closest layer to users. Thanks to the Metaverse people will have access to a variety of experiences that are currently unavailable.

The foundation of this architecture is an industrial division based on the anticipated market's value chain. On the other side, authors of [9] proposed a general three-layer architecture for the Metaverse from a more macro perspective:

1. Infrastructure layer - establishes the fundamental and physical requirements, including blockchain, network, and computational power.
2. Interaction layer - the Metaverse's contents are created in this layer.
3. Ecosystem layer - a parallel digital universe or Metaverse. AI, economics, and user-generated content are all part of this layer.

As can be seen, the term "Metaverse" is very general. Applications of the Metaverse are used in all significant fields, including education and learning, gaming, travel and tourism, healthcare, banking and finance, real estate, remote working, social media, entertainment, etc.

III. EDUCATIONAL METAVERSE

The Metaverse, a perpetual multi-user setting where physical reality and digital virtuality coexist, envisions a digital environment where education is just as accurate and effective as it is in conventional classrooms. According to [17], four factors are the causes of the Metaverse's emergence in education: rapid advancement in technology, the unavoidable use of virtual communication, the consumption patterns of cultural goods altered by the so-called Generation Z, and the widespread use of mobile devices and access to the Internet at all times and from any location that has made the Metaverse accessible to everyone. Hence, a Metaverse in the context of education is defined as a brand-new learning environment created through the promotion of Metaverse technology, which includes four types: augmented reality, life logging, mirror worlds, and virtual reality [2, 5, 18]. According to [19], the Metaverse has 5C characteristics: Canon, Creator, Currency, Continuity, and Connectivity, while authors of [20] outlined five Metaverse potential application scenarios for education: learning platforms, immersive curricula, virtual schools, twin campuses, and open universities. The world's population anticipates the Metaverse will have the greatest impact on virtual education and training (66%) according to a study by Ipsos and the World Economic Forum performed in 2022 (Fig. 1) [21].

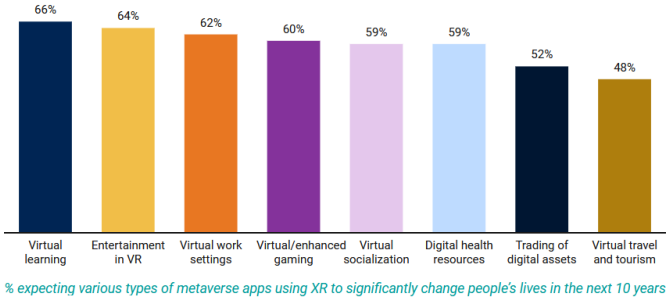

Fig. 1. The effects of Metaverse applications on people's lives [21]

Although the educational Metaverse is still in its infancy, a number of colleges and universities are starting to experiment with the "metaversity" concept in order to boost remote student engagement and offer more opportunities for experiential learning [22].

According to the study presented in [23], natural science, mathematics, and engineering accounted for 53% of the Metaverse research studies, with general education coming in at 15% and the arts and humanities at 11% (Fig. 2). Natural science, mathematics, and engineering are encouraged to use Metaverse because it can offer technical support for the particular fields, assistance for students in making connections between experiments and virtual objects, and autonomous tutoring systems based on user interaction data mining.

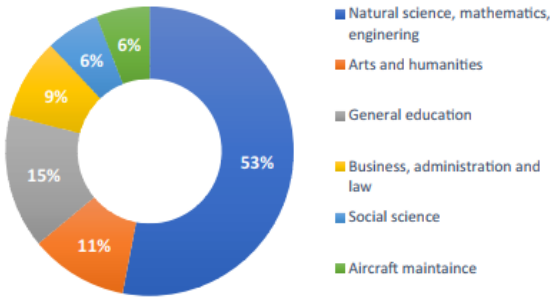

Fig. 2. The distribution of Metaverse research in the field of education [23]

A. *Benefits of the Metaverse in engineering education*

The Metaverse can extend traditional learning by offering otherwise impossible experiences, as it offers greater customization and creativity, and lower risk. When used in educational processes, the Metaverse promotes student interaction, gives both students and educators the chance to try out novel and creative methods of teaching and learning, and increases students' motivation and engagement with the academic community [3]. Due to these features, the Metaverse

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has a significant impact on the educational sector. In other words, the Metaverse has the power to completely alter the way we approach education, particularly in disciplines like engineering education where there is a need for hands-on training. Possible advantages of using the Metaverse in engineering education include the following [2, 3, 6, 23-26]:

- Virtual 3D classrooms and laboratories: For both students and educators, the use of the Metaverse in education should be a reflection of the real-world learning environment. In the other words, the Metaverse is crucial to transforming the traditional static educational model into a dynamic model. To bring education into the Metaverse, a virtual version of the traditional classroom or laboratory - a digital learning environment where educators and students can collaborate and where physical and virtual reality are integrated - can be created. Hence, Metaverse allows for the creation of 3D virtual classrooms and laboratories that can be used in various engineering courses, enabling educators and students to interact with one another virtually, simulating interactions in the real world. Immersive training programs that are appropriate for each engineering course must be created in this environment.
- Digital and interdisciplinary learning: Having in mind that engineering studies require extensive knowledge of the fundamentals as well as some laboratory or experimentation experience, thanks to Metaverse students have access to immersive learning environments and virtual learning resources. Metaverse enables the virtual environment that replicates real-world scenarios where students can conduct scientific experiments that in the real world could be dangerous, irreversible, or toxic, that might not be possible, require a lot of finances and resources, react slowly, or require extensive long-term records and observations. The Metaverse has the power to lower subject barriers and encourage interdisciplinary study. In this way, students can diagnose potential equipment, system, or process issues or improper behavior, as well as fix the flaws, much more easily, cheaply, and quickly.
- Accessibility: In the Metaverse, people are not limited by space and time thanks to high-speed networks and computer technologies. Anyone can take a class or a lecture thanks to the Metaverse and its application in education. Students can now enroll in online courses and training programs, access learning resources, design various scenarios for the use of actual devices, use simulations to complete predetermined laboratory tasks, and study from anywhere in the world and in real-time. This vastly expands students' opportunities to acquire knowledge and skills more quickly than ever before, especially those who face greater barriers to education.
- Personalized learning, increased student motivation, improved learning speed, and overall better learning experience: Placing the student at the center of the educational process and utilizing a variety of situations, methods, tools, and forms of learning and assessment may increase motivation for learning as well as the speed of learning. Knowledge of specialized engineering-related topics that are either too risky, too far away or too hard to access to be taught in a traditional classroom is of utmost importance for successful student knowledge acquisition. By better understanding subject material through 3D simulations that completely occupy a student's vision and attention, Metaverse learners experience less distraction and learn faster. The ability for students to think strategically and comprehensively, solve problems, and develop other skills important in the real world, may be enhanced in the educational Metaverse. The ability to participate in extracurricular activities and efficiently handle administrative tasks are two additional experiences that can be transferred in Metaverse from traditional educational settings.
- Enhanced teamwork and collaboration: The educator-student and student-student relationships benefit from the Metaverse because there are no physical or temporal boundaries. In other words, in the Metaverse, students can use their avatars to interact with educators and communicate with classmates. Hence, with the potential for collaborative learning and a high level of interactivity, Metaverse can offer students an immersive learning environment. Students collaborate in virtual settings and exchange ideas, strategies, and content to advance their academic and personal growth.
- Novel educator’s role: The use of the Metaverse in education necessitates a shift in the traditional role of the educator. Educators can introduce students to various realistic engineering-related scenarios in a Metaverse where they can be engaged in activities and then discuss what they learned and discovered.

B. Challenges associated with the educational Metaverse

Despite the benefits mentioned above, the creation of the Metaverse and its application in engineering education poses unique and general challenges that must be addressed [1, 2, 6, 12, 24, 27-29]:

- Technology and equipment: The Metaverse's hardware and software designs and frameworks serve as the basis for educational practices. Potential issues with equipment and technology may slow down the use of the Metaverse in

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education. Affordable smart devices with good designs are necessary for students and educators to move to the educational Metaverse. It is also important to consider how to accommodate the Metaverse's requirements for free access, high fidelity, visualization, immersion, and multi-sensory interaction when designing the user interface, particularly in the field of engineering education. In other words, due to the complexity of the necessary technologies, tools, hardware, and software to create 3D virtual educational environments where a variety of engineering courses can be realized, it is essential to have the necessary resources and an ICT infrastructure that is well-designed and scalable. Having fast, dependable, and accessible connectivity, keeping software updated, and being prepared for any potential issues is mandatory. Even though the adoption of the Metaverse in engineering education is still in its infancy, it will undoubtedly accelerate with the rapid development of VR, DTs, IoT, and 5G/6G networks. However, the implementation of the Metaverse in education lacks high-level design, systematic planning, and explicit development goals.

- Teaching and learning content and techniques: In engineering education, adopting the educational Metaverse presents unique challenges for educators. The difficulties for the educator revolve around familiarizing themselves with the Metaverse environment and the virtual classroom where the class is held as well as adapting content for delivery in the Metaverse. Spending time with the Metaverse's menu, navigation, avatar-building, and other constantly-added features is necessary to become familiar with it. Therefore, educators should adopt a new way of thinking, actively comprehend and adopt the knowledge and technology associated with the educational Metaverse, enhance their information literacy, actively investigate new teaching theories, principles, methods, and designs, upgrade their pedagogical approaches and course curricula, adapt teaching to the learning rhythms of each student, provide the necessary assistance and work to prevent fails. Students in engineering education should also work to increase their information literacy, try to adjust to the new educational style, find appropriate learning strategies, and work together to support the modernization of engineering education.
- Cybersecurity issues: The vulnerability of data is one of the main issues because so much important personal information of students, educators, and other relevant personnel is easily accessible and may be used for unethical purposes. In order to commit fraud and harm a user's reputation, cybercriminals can easily impersonate them in the Metaverse by spoofing their identities and adopting their 3D avatars. Once it occurs, it will invade the users' privacy and even negatively impact their daily lives. Additionally, both educators' and students' work and creations run the risk of being plagiarized. Therefore, they may experience trust issues as a result of the complexity of the sources of data and information. In the Metaverse, they will always struggle to determine whether the people they are communicating with are real or not. Hence, HEIs and educational participants can only use a Metaverse if they are confident that it will perform as expected.
- Legal and ethical issues: In the educational Metaverse, educators, students, and other relevant personnel enter as digital humans and virtual avatars to impart or acquire knowledge and skills. They can access the Metaverse anywhere in the world because of the high level of freedom. There are still many unanswered questions regarding the ownership of digital assets. The use of avatars to represent users as their virtual twins raise moral and legal concerns. Although using the Metaverse for educational purposes offers a useful learning mode, it may also bring up potential moral concerns like violating people's privacy, bullying, insulting, religious conflicts, data theft, and educational inequality. Hence, the creation of a well-structured Metaverse with rules and ecosystems is, therefore, a pressing issue.
- Standardization and regulations: The existing Metaverse standards, which are mainly focused on enabling seamless communication between the physical and virtual worlds, are summarized in [30]. However, in a Metaverse-based educational environment, it is urgently necessary to establish and apply strict rules. In other words, it is necessary to have uniform technical standards and protocols across all physical and virtual spaces because the educational Metaverse still struggles with connecting the underlying supporting technologies of various ecosystems. Educational Metaverse should incorporate the fundamental principles of information security, such as Confidentiality, Integrity, and Availability. In order to protect the rights of the avatar in the Metaverse, laws, and regulations must be put in place. Establishing standards and criteria that distinguish a legal avatar from the real-life person who owns the avatar is one of the most challenging problems.
- A preference for virtual over real: Students' preference for the virtual world over the real one

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could have a negative impact on interpersonal relationships due to the Metaverse. As a result, there are fewer direct interactions between people in the real world, and those who do not want to deal with the difficulties of daily life turn to the virtual world as a safe place. This may also cause addiction problems which affect students' physical and mental health and can result in anti-social or extravagant behaviors. Because of it, students will need some guidance to balance their time in and out of the Metaverse world and pay attention to real-world interaction.

IV. Conclusion

The COVID-19 pandemic has presented a significant challenge for engineering education as the field heavily relies on practical exercises and hands-on experience, which are difficult to replicate in an online learning environment. Engineering education demands a high level of interactivity and engagement, and HEIs have been working hard to incorporate immersive technologies into their educational practices to meet these demands. One promising solution is the use of Metaverse, a virtual world that can offer a more interactive and engaging learning experience. With the advancement of Metaverse-related technologies, such as wearable gadgets, high-speed computers and networks, and sensing technologies, it is becoming increasingly feasible to use Metaverse in engineering education. However, there are several challenges that need to be addressed, including cybersecurity issues, privacy, trust, legal and ethical concerns, as well as the need for appropriate technology infrastructure, standards, and regulations. Despite these challenges, the educational Metaverse has the potential to transform engineering education into a more innovative, cutting-edge, and relevant field, providing students with a highly engaging and immersive learning experience.

References

[1] H. Wang, D. Chen, Q. Deng, "The Formation, Development and Research Prospect of Educational Metaverse," *Education Journal* 2022; 11(5): 254-260

[2] X. Zhang, Y. Chen, L. Hu, Y. Wang, "The Metaverse in education: Definition, framework, features, potential applications, challenges, and future research topics," *Front. Psychol*. 13, 1–18. 2022.

[3] G.-J. Hwang, S.-Y. Chien, "Definition, roles, and potential research issues of the Metaverse in education: an artificial intelligence perspective," *Comput. Educ. Artif. Intell.* 3:100082. 2022.

[4] M. Maksimović, N. Davidović, "The role of Digital Twin technology in transforming engineering education," *9th International scientific conference Technics and Informatics in Education* – TIE 2022, 264-270.

[5] B. Kye, N. Han, E. Kim, Y. Park, S. Jo, S., "Educational applications of Metaverse: Possibilities and limitations," *J. Educ. Eval. Health Prof.* 2021, 18, 1149230

[6] H. Lin, S. Wan, W. Gan, J. Chen, H.-C. Chao, "Metaverse in Education: Vision, Opportunities, and Challenges," IEEE BigData, 2022

[7] J. Wiles, "What Is a Metaverse? And Should You Be Buying In?", 2022. [Online]: https://www.gartner.com/en/articles/what-is-a-metaverse

[8] Y. Nezami, "What is the metaverse and why does it need 5G to succeed? The metaverse 5G relationship explained," 2022. [Online]: https://www.ericsson.com/en/blog/2022/4/why-metaverse-needs-5g

[9] H. Duan, J. Li, S. Fan, Z., Lin, X. Wu, W. Cai, "Metaverse for social good," Proceedings of the 29th ACM International Conference on Multimedia, 2021. 153–161. https://doi.org/10.1145/3474085.3479238J.

[10] T. Huynh-The, T. R. Gadekallu, W. Wang, G. Yenduri, P. Ranaweera, Q. V. Pham, D. B. da Costa, M. Liyanage, "Blockchain for the Metaverse: A review," *Future Generation Computer Systems*, Vol. 143, 2023, pp. Pages 401-419,

[11] S. Banaeian Far, A. Imani Rad, "Applying Digital Twins in Metaverse: User Interface, Security and Privacy Challenges," *Journal of Metaverse*, 2022, 2 (1), 8-16.

[12] S. Kaddoura S, F. Al Husseiny F. "The rising trend of Metaverse in education: challenges, opportunities, and ethical considerations," *PeerJ Comput. Sci*. 2023. 9:e1252 DOI 10.7717/peerj-cs.1252

[13] Gartner, *Predicts 2022: 4 Technology Bets for Building the Digital Future*. 2022. [Online]: https://www.businesswire.com/news/home/20220207005085/en.

[14] Metaverse Market, *Metaverse Market by Component, Vertical and Regian - Global Forecast to 2027*, 2022, [Online]: https://www.marketsandmarkets.com/Market-Reports/metaverse-market-166893905.html

[15] J. Radoff, "The Metaverse Value-Chain," 2021 [Online]: https://medium.com/building-the-Metaverse/the-Metaverse-value-chain-afcf9e09e3a7

[16] C. BasuMallick, "What Is the Metaverse? Meaning, Features, and Importance," Spiceworks, 2022. [Online]: https://www.spiceworks.com/tech/artificial-intelligence/articles/what-is-Metaverse/

[17] W. Suh, S. Ahn, "Utilizing the Metaverse for learner-centered constructivist education in the post-pandemic era: An analysis of elementary school students," *J. Intell.* 2022, 10, 17.

[18] G. Wang, C. Shin, "Influencing Factors of Usage Intention of Metaverse Education Application Platform: Empirical Evidence Based on PPM and TAM Models," *Sustainability* 2022, 14, 17037.

[19] S.Y. Ko, H.K. Jeong, J.I. Kim, Y.T. Shin, "The Concept and development directions of Metaverse," Korea Inf. Proc. Soc. Rev. 2021, 28, 7–16.

[20] Y. Hu, Q. Ni, X. Yang, "International Research Progress, Trends and Challenges of Metaverse in Education," *Mod. Distance Learn. Res.* 2022, 34, 37–46

[21] N. Boyon, "Enthusiasm for the metaverse and extended reality is highest in emerging countries," Ipsos, 2022. [Online]: https://www.ipsos.com/en/global-advisor-metaverse-extended-reality-may-2022

[22] Analytic Insights, *Top 10 Universities offering Metaverse Related Research, Courses & More*, 2022. [Online]: https://www.analyticsinsight.net/top-10-universities-offering-Metaverse-related-research-courses-more/

[23] A. Tlili, R. Huang, B. Shehata, D. Liu, J. Zhao, A.H.S. Metwally, H. Wang, M. Denden, A. Bozkurt, L. H. Lee, et al. "Is Metaverse in education a blessing or a curse: A combined content and bibliometric analysis," *Smart Learn. Environ.* 2022, 9, 1–31.

[24] M. J. Sá, S. Serpa, "Metaverse as a Learning Environment: Some Considerations," *Sustainability* 2023, 15, 2186.

[25] K. Yue, "Breaking Down the Barrier Between Teachers and Students by Using Metaverse Technology in Education: Based on a Survey and Analysis of Shenzhen City, China," 13th International Conference on E-Education, E-Business, E-Management, and E-Learning (IC4E 2022), pp. 40–44

[26] A. Takyar, "Metaverse in Education," LeewayHertz [Online]: https://www.leewayhertz.com/Metaverse-in-education/

[27] J. Wu, G. Gao, "Edu-Metaverse: Internet Education Form with Fusion of Virtual and Reality," 8th International Conference on Humanities and Social Science Research (ICHSSR 2022), pp. 1082–1085.

[28] V. Khan, I. I. Basith M. Boyd, "Application of Metaverse as an Immersive Teaching Tool in Engineering Technology Classrooms," 2022 ASEE IL-IN Section Conference | Paper ID 36131

[29] Chainyard, "The Metaverse – Key Features and Challenges," 2022. [Online]: https://chainyard.com/web3/the-Metaverse-key-features-and-challenges/

[30] D. B. Rawat, H. El Alami, "Metaverse: Requirements, Architecture, Standards, Status, Challenges, and Perspectives," arXiv preprint, *arXiv:2302.01125v1*, 2023.

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