Metaverse in Education: What Has Been Done so Far? A Systematic Literature Review to Map Benefits and Limitations and to Set Future Research and Application Directions

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Keywords: Metaverse, Education, Technology, Systematic Literature Review, Barriers, Benefits.

Abstract: The use of Metaverse and related technologies in educational field comes out of a need to solve a series of challenges arising from the advent of fifth industrial revolution and from the Covid-19 pandemic period. Persistent improvements in the learning process of students and, more broadly, people, result from the adoption of platforms that integrate the Metaverse, enabling greater use of virtual objects in game-related contexts. However, given the rapid evolution of this technological field, there is a lack of clear understanding of the current Metaverse advancements in education. In this context, our study aims, through a Systematic Literature Review method, to explore recent developments arising from the use of the Metaverse in education, with the goal of identifying the advantages and limitations that have emerged in different educational activities. After conducting preliminary bibliometric analysis to assess the performance of our analysis sample, proceeded with a content analysis of 41 papers that describe case study of the Metaverse in education. This analysis focused on several aspects. From the analysis carried out, the use of Metaverse-enabling technologies generated a significant improvement in the learning process, which was much more immersive and interactive. The value of the study lies in providing a list of benefits and limitations derived from applied case studies. These findings serve as a guideline for the implementation of future Metaverse-based educational experience, benefiting educational institutions, students, researchers, and business trainers alike.

1 INTRODUCTION

Nowadays there is an increasing global attention on Metaverse which led to the rapid adoption of Metaverse technologies by businesses and governments for several purposes, and to the rapid increasing of scientific knowledge of this topic (Giang Barrera and Shah 2023). The Metaverse, a fusion of "meta" (implying transcendence) and "universe", is a decentralized three-dimensional online environment that is persistent, immersive, and always accessible. There, users, represented by avatars, can interact socially and economically in creative and collaborative ways, within virtual spaces separated from the real physical world (Ritterbusch and Teichmann 2023).

In the Metaverse, individuals can engage in various activities such as discussing common issues, collaborating on projects, enjoying gaming experiences, and learning through experimentation or problem solving (Hwang and Chien 2022). In recent years, many applications related to the Metaverse were developed worldwide, particularly by computer gaming companies and social networks (such as Facebook) (Wiederhold 2022).

The potential benefits arising from the integration of the Metaverse in the field of education are emerging (Fakhri, Silvianita, and Yulias 2021). This is because the Metaverse assumes significant importance in the educational sector, offering unique opportunities for learning and interaction (Prakash et al. 2023). The Metaverse offers the opportunity to

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Latino, M., Chiara De Lorenzi, M., Arcuti, M. and Corallo, A.
Metaverse in Education: What Has Been Done so Far? A Systematic Literature Review to Map Benefits and Limitations and to Set Future Research and Application Directions.
DOI: 10.5220/0012753300003693

In *Proceedings of the 16th International Conference on Computer Supported Education (CSEDU 2024) - Volume 1*, pages 735-743
ISBN: 978-989-758-697-2; ISSN: 2184-5026

provide a more engaging and interactive learning experience, cater to individual learning styles, and reach a broader audience (Zahra et al. 2021). It also provides a safe and controlled environment for conducting experiments and simulations, that would be challenging or impossible in the physical world.

To the best of our knowledge, two studies in the Metaverse research have stream focused on provide a state of the art of Metaverse applications in education. Specifically, Pradana and Elisa (2023) synthesized advancements in the Metaverse within education, reporting that the most significant articles words are "education", "application" and "Metaverse". However, the research methodology described in the study not provide sufficient information on the type of studies used in the analysis sample. Lin et al. (2022) conducted a literature review, to investigate the benefits derived from the use of Metaverse technologies in the field of education, without following a systematic review approach. Hence, the necessity to comprehend the current utilization of Metaverse technologies in training activities remains apparent, beginning with practical evidence found in application case studies. With the aim of addressing this emerging gap, this study aims to unveil the recent advancements of Metaverse in education, mapping the benefits and limitations of applying these technologies in training activities. Specifically, adopting a systematic literature review (SLR) approach based on PRISMA guidelines, we preliminary analysed a sample of 62 studies using bibliometric analysis with the purpose to describe the performance of our analysis sample. After that, performing a content analysis, we identified a sample of 41 of applicative case studies of Metaverse in education mapping: the aim of the case study, the subject taught using Metaverse, the target of students, the technologies used and the impacts of Metaverse - based teaching on the students.

The reminder of this article is organized as follows. In Section 2, we presented the background in order to show the state of art about Metaverse technologies and their application in the educational field. In Section 3, we described data and methods employed in the study. In Section 4, we presented the main results of our analysis and the related discussions. Finally, in Section 5 closes the study summarizing closing remarks, limitations and follow-ups.

2 BACKGROUND

2.1 Metaverse Technologies

In a Metaverse environment, several technological elements can be utilized to construct the ideal virtual world depending on the goal to be achieved (e.g., avatar, currency, good). To take advantage from the Metaverse, it is not enough to know what it is and for whom it is, but it is necessary to know how to use it. For this reason, it is necessary to make explicit what technologies and platforms support the Metaverse development. The essential technologies for comprehending and utilizing the Metaverse include Virtual Reality (VR), Augmented Reality (AR), and Mixed Reality (MR), collectively encapsulated under the technological term of eXtended Reality (XR) (Mystakidis, Fragkaki, and Filippousis 2021). Table 1 reported the description of this technologies.

Currently, the Metaverse provides highly immersive virtual gaming experiences, allowing users to interact with three-dimensional virtual worlds.

Table 1: Description of Metaverse's Technologies.

Augmented Reality. It combines physical and virtual **world**s **incorporat**ing **digital input**s and **virtual element**s **into the physical environment with the intent to enhance it. This thanks to the use of devices, such as smartphones, tablets and glasses, it will be possible to observe digital artifacts.** (Papagiannis 2017)
Virtual Reality. It creates a synthetic, digital environment separated **from physical** one**, within which the user can interact intuitively. Such technology can be accessed from standard computing devices**, **head-mounted displays or headsets.** (Bekele et al. 2018)
Mixed Reality. It represents any environment that consists of a fusion of real and virtual objects. Mixed reality environments in which the real world is augmented with virtual content are called augmented reality (AR), while those in which most of the content is virtual but there is some awareness or inclusion of real-world objects are called augmented virtuality (AV) (Milgram et al. 1995)
Extended Reality. It, leveraging on **stereoscopic displays that can convey depth perception**, **activate**s **a wide user field of view that can range from 90 to 180 degrees. XR systems also offer 3D auditory experiences that enable the construction of soundscapes that decisively enhance immersion in the virtual world. Such systems allow active interaction using motion controllers. These are handheld input devices with grips, buttons, and toggles through which users can touch, grasp, manipulate, and operate virtual objects (**Rakkolainen et al. 2021)

Within the Metaverse, games range from realistic simulations to fantasy and social experiences. Artists and event planners are leveraging it to organize virtual concerts, festivals, and social events, allowing viewers to participate in live performances in a virtual environment, interacting with both other participants and the artists themselves (Oliveira and Cruz 2023). The integration of the Metaverse into tourism offers new opportunities for travelers to engage and discover, introducing novel ways of virtual exploration both before, during and after travel. Tourists can immerse themselves in virtual experiences that replicate tourist activities, such as scuba diving, scenic flights, or walks through natural landscapes (Monaco and Sacchi 2023). The integration of the Metaverse into real estate offers several benefits, improving the experience associated with buying, selling, and managing properties, making it more interactive, efficient, and engaging. Through the Metaverse, retailers can create virtual stores, enabling shoppers to explore and purchase products in an interactive virtual environment. The integration of the Metaverse into the field of medicine promises to profoundly revolutionize medical practice, improving training, research and patient care through more immersive and interactive virtual experiences.

2.2 Technologies in Education

The education can be delineated as the specific activities conducted by educators and teachers, in specific places, such as schools. In a broader perspective, education encompasses the entire learning process of each individual, incorporating vocational training, skill development and the refinement of personal thinking (Friesen 2017). With the advance of the digital age and the expansion of the Internet, education has undergone further significant changes (Collins and Halverson 2018). The availability of online information has transformed access to knowledge, opening up new horizons for independent and personalized learning. Educational technologies, such as e-learning platforms, interactive simulations, and multimedia resources, have expanded the ways of teaching and learning (Retnawati 2019). Training methods within a modern educational paradigm must be designed considering the teaching characteristics and contents that can be provided to the student toward personal and virtual educational environment (Yavich and Starichenko 2017). Since the outbreak of COVID-19, Metaverse has gained an even more prominent role in the education sector, presenting innovative solutions to address the challenges related to distance education and to enhance the learning process. Metaverse technologies have ushered in new perspectives in the educational sector, providing cutting-edge tools and immersive experiences to enrich the learning path (Rossi et al. 2023). For example, according Calvert and Abadia (2020), VR allows students the opportunity to fully immerse themselves in three-dimensional virtual environments. Virtual classrooms, labs, and realistic simulations can be developed to provide more immersive learning experiences. AR learning books can provide interactive content, displaying contextualized information in the surrounding environment with the result to enrich the students' experience Di Serio, Ibáñez, and Kloos (2013). MR allows students to interact with virtual objects embedded in the real world. This can be leveraged to create more realistic educational experiences, (Vasilevski and Birt 2020).

The implementation of these technologies will go a long way toward improving student engagement, enabling students to learn more engagingly through simulations, explorations, and interactions within digital environments (Lindgren et al. 2016). The goal is to make learning more dynamic, hands-on, and tailored to students' needs by harnessing the potential of virtual technologies to enrich the educational experience (Dalgarno and Lee 2010).

Therefore, to implement a "modern" educational paradigm, the training methods must focus on the use of personal educational environments within the virtual learning context (Lin et al. 2022). For this purpose the design process of modern educational activity is focused to define the characteristics of the Virtual Environment for Education (VEE) (Yavich and Starichenko 2017). A VEE is a virtual environment built on a specific pedagogical model, which complements or implies educational objectives. It provides users with experiences that would not otherwise be accessible in the physical world, contributing to specific learning outcomes (Natsis et al. 2012). Therefore, it is crucial to adapt the new educational system to preserve its accessibility and ensure its sustainability overtime. For example, according to Lehikko (2021), Metaverse enables an immersive interactive experience within which students will find themselves more immersed in a teaching environment, thus going on to facilitate more effective learning through a realistic experience that includes observation and practice. Indeed, as cited by Thompson et al., (2021), thanks to digital technologies, the Metaverse can facilitate students in observing elements that are difficult to access directly

in the real world, such as molecules or biological cells, through a microscopic perspective. Such utilization will consequently allow for a reduction in learning costs, as in many disciplines, such as chemistry and physics, conducting experiments is often necessary. Similarly, if students engage in high-risk activities, such as handling flammable or explosive materials, or participate in simulated aircraft accidents, the operational risk to students will be significantly reduced (Camilleri 2023). Furthermore, according to Laine and Lee (2023), the use of Metaverse in education offers opportunities to operate without time constraints. For example, historical events can be replayed and experienced, eliminating the need for students to imagine or rely on books and videos. Another achievable benefit is to increase the involvement of the student thanks to the possibility to create personalized avatars based on their personal preferences (Rasheed, San, and Kvamsdal (2020). Through their avatars, everyone can see each other, easily share files, or participate in playful activities. These features enhance relationships between students and teachers, fostering friendships among classmates (Kanematsu et al., 2010).

The main purpose of Metaverse applications in the educational field is to go on to create a total immersion of the user within the virtual environment (Quatera 2022). This is possible toward: a sociopsychological immersion and multimodal immersion. In this way, the user is fully engaged in a completely artificial space.

To ensure an efficient learning, a technological platform for education can be established according four steps (Quatera 2022):

• Phase 1 - Perception: involves going to use devices that take advantage of virtual reality and augmented reality technologies with the goal of stimulating the user and increasing their degree of perception of the multimodal experience they are in.

• Phase 2 - Interaction: consists of allowing users to interact with the virtual world by going to influence the flow of content.

• Phase 3 - Immersion: consists of enabling the user to develop greater autonomy in the virtual environment by guiding the learning procedure with their decisions using applications that take advantage of virtual reality.

• Phase 4 - Presence: users perceive presence in the new virtual space of themselves in relation to other users thanks to problem solving and gamification elements.

3 METHODS AND DATA

In order to achieve the proposed aim, we conducted a literature review as independent studies (Kraus et al. 2022) and in particular, this SLR is domain focused. This method is useful to systematize and share the results about a specific body of literature (Creswell and Creswell 2017) and when the purpose of the study is to map a research field, identify gaps and develop the future research agenda (Rojon, Okupe, and McDowall 2021; Tang et al. 2023). To identify the sample of analysis, a search scheme and the inclusion and exclusion criteria needed to be defined (in our research, the sole inclusion criterion was to utilize only articles in English). The following search scheme was applied in Scopus database: TITLE-ABS-KEY (("metaverse" OR "virtual reality" OR "augmented reality" OR "mixed reality" OR "extended reality") AND "technolog*" AND "elearning" AND "student")) (Search data: 31st January 2024) leading to a sample of 61 studies. The selection of query keywords was made through a focus group of experts and academics who conducted a screening of possible related terms. The review protocol was established according to PRISMA flowchart (Page et al. 2021) (Figure 1).

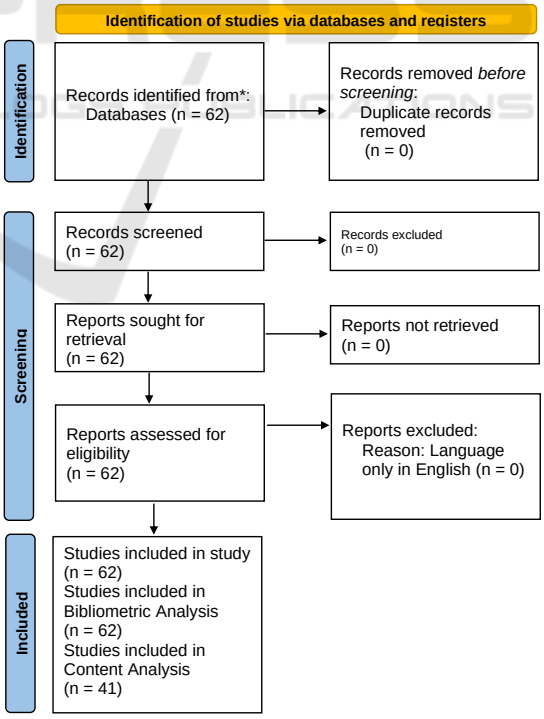

Figure 1: PRISMA Protocol.

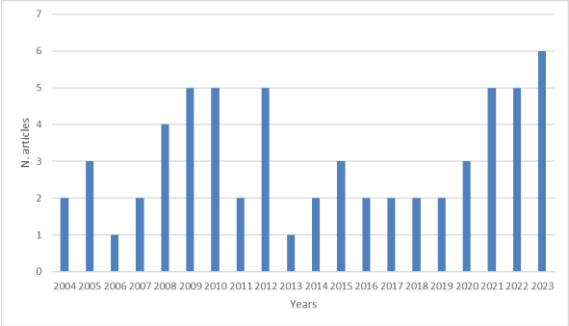

Figure 2: Annual Scientific Production.

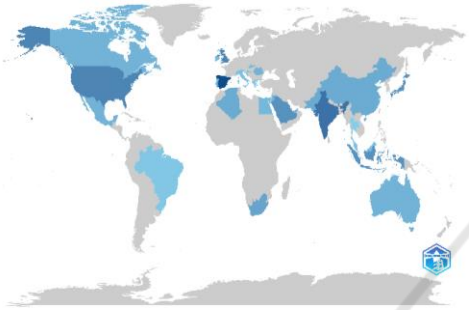

Figure 3: Country Scientific Production.

The sample was analysed by using bibliometric analysis and content analysis. Specifically, bibliometrics analysis was carried out through Bibliometrix tool (Aria and Cuccurullo 2017) and allowed to identify the following performance indicators: annual scientific production, most relevant sources, country scientific production and trend topic. This analysis is useful to understand the current state of improvement of the topic in the academic scenario. Specifically, our analysis reveals that the temporal publications trend shows two peaks of scientific production in 2008 and 2012 and a period of growth from 2019 onwards that continues to this day (Figure 2). The most relevant sources of contributions are conferences studies and lecture notes. The geographical distribution of production is located in Europe with particular reference to Spain, United Kingdom and Italy), America and the eastern area with a greater density in India (Figure 3). Finally, the bibliometric analysis traced the trending topic of the studies, showing among the most recurring words VR (TF=34), e-learning (TF=28), and students (TF=24). After this first level of analysis, we screened the sample of 62 papers by reading the title and abstract in order to identify only those studies that dealt with an applicative case study on the use of Metaverse technologies in education. A final sample of 41 eligible studies were identified and analysed using content analysis to discover: the aim of the case study, the subject taught using Metaverse, the target of students, the technologies used and the impacts of Metaverse - based teaching on the students (details in Section 4). The full text reading during content analysis revealed that only 34 studies described experiences from applicative case studies.

4 FINDING AND DISCUSSIONS

4.1 Results from Content Analysis

The content analysis was conducted by the team of researchers who conducted the study. The analysis commenced with the complete reading of the 41 papers deemed eligible based on the initial title and abstract screening, as explained in the previous section.

The purposes of the studies in our sample can be referred to the following three categories: i) assessing the performance of Metaverse technologies in learning (40%); ii) assessing of the impacts generated by technology on users (20,5%), and iii) assessing benefits perceived by end-users during the adoption of Metaverse technologies in learning activities (37%) and iv) other purpose (2,5%).

Analyzing the disciplinary context, we retrieved that Metaverse was used 94% in educational context for training students, and 6% in corporate training context for training employees. Specifically, in the educational context, 44% use Metaverse in general education, 5.8% in primary and secondary school education, and 50.2% in university education.

Interesting to note that the target of students involved in Metaverse-based learning experience was composed by students (85%), professionals and technicians with a focus on medical and manufacturing industries (9.5%) and teachers both in the university and primary/secondary school settings (9.5%). In the student category, 45.1% are general students, 3.3% are primary and secondary school students, and 51.6% are university students. Among university students, 80% are enrolled in STEM subjects (such as engineering, architecture, chemistry, and agriculture), and the remaining 20% are involved in foreign language programs.

Regarding technology, the analysis unveiled a different use of the several virtual technologies: VR (51.1%), AR (18.6%), MR (9.3%), XR (2.3%), platform (4.7%), and other technologies such as Information Communication Technology, integration of Microsoft Teams, Mobile clicker, Simulation, eLearning Technologies, iBeacon Technology, Virtual Agent (14%).

The analysis of the impacts generated on students by the use of Metaverse technologies in learning activities allowed us to identify both benefits and limitations. Specifically, seven macro-categories of benefits were discovered: i) increase the student motivation and enjoyment; ii) facilitate teaching; iii) improve technical and professional skills; iv) increased the student engagement; v) improve learning; vi) enhance the student knowledge; vii) increase the interaction between students and teachers. The only identified limitation is the perception, by both teachers and students, of a lack of detachment from teaching/learning activities since who perceived themselves as constantly connected even outside actual work or study times.

4.2 Discussions

Through our SLR, aimed at identifying the benefits and limitations of applying Metaverse technologies in the field of education, we observed that the results from bibliometric analysis confirm an increased attention and scientific production on the Metaverse-based education in recent years, particularly from 2019 onward (Giang Barrera and Shah 2023). The prevalence of conference contributions in the literature indicates that the theme of the study and its applications in case studies are continually evolving and gaining prominence (Fakhri, Silvianita, and Yulias 2021). As supported by Zahra et al. (2021), our analysis affirms that the focus is on providing a more engaging and interactive learning experience, catering to individual learning styles, and reaching a broader audience. This shows that currently the theme of the metaverse in the field of education is progressively maturing, demonstrating how theory can be effectively applied in practice.

The case studies in the analyzed works focus on evaluating the potential of specific Metaverse technology in the education sector, assessing the impacts of the technology on users, and demonstrating the benefits of Metaverse technologies to end-users. According to Quatera (2022), Metaverse usage proves useful in various educational contexts. Our results confirm applications not only in primary, secondary, and university education context but also in the field of corporate training. The application in university education, especially in support of STEM disciplines, supports the notion, as advocated by Thompson et al. (2021), that Metaverse technologies facilitate the observation of phenomena related to sciences that are typically more challenging to observe in the real world. The Metaverse-specific technologies identified in the study, with the perspective of enabling the development of cutting-edge tools and providing immersive experiences to enrich the learning journey (Rossi et al. 2023), align with the benefits of interaction (Theron, Garcia-Holgado, and Marcos-Pablos 2021; Hsiung 2018). Scholars may focus on observing and analyzing the perception of the use of metaverse technologies by the involved actors. Moreover, much can still be done in the industrial field for personnel training through new training approaches utilizing the metaverse.

Finally, the benefits and limitation outlined by this study underscore, as asserted by (Al-Ghaili et al. 2022) and (Lehikko 2021), that Metaverse technologies can enhance motivation and enjoyment of students, facilitate teaching, improve technical/professional skills, increase engagement, enhance learning, improve knowledge, and boost interaction.

This study presents theoretical implications by contributing to the current state of the art on the topic, delving into the most utilized Metaverse technologies and the target users interested and involved in the subject. The presence of most case study in STEM learning suggests the possibility to foster this research stream proposing applicative case study in different subject, especially ones in which visual impact could be relevant (e.g., art). Moreover, our results open the way to the involvement of emergent technologies to be used in a combined manner with Metaverse (e.g., artificial intelligence).

Practical implications are also evident, as our study can serve as a starting point for those experimenting with the ways and technologies that can be used in the field of education. Therefore, educational institutions, students, researchers, and business trainers can benefit from our study by increasing awareness about the aim of using Metaverse technologies, the technologies to use, the potential applications of these technologies in STEM training, the benefits for students, and the limitations to overcome.

5 CLOSING REMARKS, LIMITS AND FOLLOW-UPS

Starting from the need to complement the current knowledge in Metaverse-based education with evidence from practical fields, this study reports insights derived from a SLR. Specifically, we analyse a sample of 62 manuscripts to uncover applicative case studies of Metaverse technologies in the educational field, with the aim of unveiling the purpose of the case study, the subject taught using Metaverse, the target audience of students, the

technologies used, and the impacts of Metaverse-based teaching on students.

The value of the study lies in providing a list of benefits and limitations coming from applicative case studies which represent a guideline in the implementation of future Metaverse-based educational experience for the benefit of educational institutions, students, researchers and business trainers.

Despite the well-established research methodology, which ensures the clarity and replicability of the study, it is important to highlight the standard limitations associated with SLR. They derive from the search keywords and database chosen, which affect and characterize the results obtained: using another set of keywords (and related combinations through Boolean operators) and other databases (such as Google Scholar or Science Direct) could have led to a different analysis sample. The experts that conducting the content analysis also had an impact on the results. Other experts might have interpreted the data differently.

Starting from these limitations, this research can be further developed by following up with the following steps: i) enlarge the current SLR reinforcing the set of keywords and/or using other database; ii) conduct an explorative study leveraging on the analysis of multiple-case studies to assess the presence of other benefits and limitations; iii) conduct a survey on a sample of students involved in Metaverse-based learning experience to investigate the perceived benefits and limitations; iv) collect data from multiple Metaverse-based learning experience in order to understand the relation between the perceived benefits and limits with the specific technologies used or the specific educational method.

ACKNOWLEDGEMENT

This work was partially supported by the EL4STEM project (Extended Learning for STEM - "Funds for basic research"), at the Department of Engineering for Innovation, University of Salento (Lecce, Italy).

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