

Metaverse in Education: a systematic review

Metaverso en Educación: una revisión sistemática

Jesús López-Belmonte
University of Granada. Ceuta, Spain
jesuslopez@ugr.es

Santiago Pozo-Sánchez
International University of La Rioja. La Rioja, Spain
josesantiago.pozo@unir.net

Antonio-José Moreno-Guerrero
University of Granada. Ceuta, Spain
ajmoreno@ugr.es

Georgios Lampropoulos
International Hellenic University. Thessaloniki, Greece
lamprop.geo@gmail.com

Abstract

The Addressing the new educational needs and requirements still remains a challenge. Moreover, due to the COVID-19 pandemic and the technological advancements, learning environments are being transformed. Metaverse is a computer-generated lifelike 3D virtual extension of the physical world as it immerses users, allows them to interact with others and with digital objects, and eliminates the constraints of distance and time differences. It is characterized by persistence, interactivity, and embodiment. The use of the metaverse in educational and training processes to create new learning environments that allow learners to function in a parallel, safe and personalized reality is gaining ground. The aim of this study is to analyze the existing research into the metaverse in the educational field. Hence, a systematic literature review has been carried out using the Web of Science (WoS) and Scopus databases. To provide more complete and constructive results, no year, educational level, or subject restrictions were set. As metaverse is a new topic and taking the inclusion and exclusion criteria into account, a total of 17 articles has been analyzed. Based on the findings, metaverse has the potential to enrich and transform education and lead to increased learning outcomes and enhanced students' engagement and motivation. Despite this fact, the use of metaverse in education is in its infancy, thus, more research and experiments should be carried out in all educational levels and populations to assess its impact and improve its effectiveness. Finally, the need for designing valid instruments to evaluate the educational experiences generated within the metaverse was evident.

Key words: metaverse, immersive reality, extended reality, educational technology, bibliometric study

Resumen

Abordar las nuevas necesidades y requerimientos educativos sigue siendo un desafío. Debido a la pandemia de COVID-19 y los avances tecnológicos, los entornos de aprendizaje se están transformando. El metaverso es una extensión virtual 3D realista del mundo físico generada por computadora, ya que sumerge a los usuarios, les permite interactuar con otros y con objetos digitales, y elimina las limitaciones de distancia y diferencias de tiempo. Se caracteriza por la inmersividad, la interactividad y la personificación. Está ganando terreno el uso del metaverso en los procesos educativos y formativos para crear nuevos entornos de aprendizaje que permitan a los aprendices desenvolverse en una realidad paralela, segura y

personalizada. El objetivo de este estudio es analizar la investigación existente sobre el metaverso en el ámbito educativo. Por lo tanto, se ha llevado a cabo una revisión sistemática de la literatura utilizando las bases de datos Web of Science (WoS) y Scopus. Para proporcionar resultados más completos y constructivos, no se establecieron restricciones de año, nivel educativo o materias. Como el metaverso es un tema nuevo y teniendo en cuenta los criterios de inclusión y exclusión, se han analizado un total de 17 artículos. Según los hallazgos, el metaverso tiene el potencial de enriquecer y transformar la educación y conducir a mejores resultados de aprendizaje y una mayor participación y motivación de los estudiantes. A pesar de este hecho, el uso del metaverso en educación es todavía preliminar, por lo que se deben realizar más investigaciones y experimentos en todos los niveles educativos y poblaciones para evaluar su impacto y mejorar su efectividad. Finalmente, se evidenció la necesidad de diseñar instrumentos válidos para evaluar las experiencias educativas generadas dentro del metaverso.

Palabras clave: metaverso, realidad inmersiva, realidad extendida, tecnología educativa, estudio bibliométrico

1. Introduction

The emergence of the COVID-19 pandemic has drastically affected every single domain of everyday life. It has rendered the need to incorporate Information Communication Technologies (ICT) and digital devices in the educational process a necessity (Daniel, 2020). The field of educational technology which refers to the use of computer software and hardware in combination with educational theories and approaches to enable technology-enhanced learning and facilitate and improve teaching and learning activities is also gaining ground (Colomo-Magaña et al., 2021; Hew et al., 2019; Januszewski & Molenda, 2013). Moreover, as students grow up in more diverse and globalized environments and have constant access to digital devices as well as personalized and dynamically changing information, their concept of effective learning and their educational requirements have changed (Anastasiadis et al., 2018). As a result, students are seeking for more meaningful, intriguing and engaging learning experiences in which they could play an active role and not be merely passive participants (López-Belmonte et al., 2021). Consequently, it is vital to study and try to comprehend how novel student-centered technology-enhanced learning experiences could impact the teaching and learning process.

Furthermore, learning is more natural, meaningful and efficient when it places students' inquiry at its core, enhances students' 21st century skills development, addresses social issues and is used in conjunction with ICT (Barab & Dede, 2007; Zeidler et al., 2005). Digital technologies and resources can help motivate students as they themselves are imbued with technology (Baynat & López, 2020). Therefore, when state-of-the-art technologies are at the forefront and used to their fullest potential in a student-centered manner, they are able to address these issues by providing deeper and more meaningful learning (Billingsley et al., 2019). In addition, with digital devices and emerging technologies being adopted in teaching and learning activities at a rapid pace (Zawacki-Richter & Latchem, 2018), non-digital and ineffective learning and teaching tools are replaced, existing educational processes are amplified and new educational methods and approaches are offered (Hughes et al., 2006).

Particular interest is shown in the implementation of immersive virtual learning environments (VLE) in education as a means to create more personalized and engaging learning experiences (Reisoğlu et al., 2017). Within these environments that can be further amplified through the use of Extended Reality (XR) technologies, students are able to safely interact with virtual content and acquire hands-on experience (Lampropoulos et al., 2021).

VLEs are designed information and social spaces that are explicitly represented and can overlap with physical environments in which educational interaction can take place through the integration of heterogeneous technologies and various pedagogical approaches (Dillenbourg et al., 2002). These environments are not only restricted to online education but can also enrich traditional classroom activities, allow learners to play an active and con-constructive role in the educational process and constitute a significant means in the creation of educational virtual communities which foster a sense of belonging. Moreover, VLEs offer affluent teaching and learning contents, improve learners' problem-solving and critical thinking skills, promote collaborative learning and communication, facilitate tracking and evaluation of academic performance and provide easy access to interactive learning resources and material (Pan et al., 2006).

Within the context of VLEs, the application of metaverse in various sectors is becoming popular due to the benefits it can potentially yield. Metaverse constitutes a computer-generated three-dimensional (3D) virtual world that allows users to interact with each other as well as with digital content and objects in real time as if they were in the real world while also overcoming the constraints of distance and time differences. Within metaverse, the real and virtual worlds coexist and users can engage in various activities while staying interconnected through virtual avatars based on the concept that one's online and offline selves do not differ (Park & Kim, 2021; Sparkes, 2021). For its realization, XR technologies are used in combination to provide users with a virtual presence within a fully digital environment. As it is also the case for virtual reality, the fundamentals of the virtual worlds created in the metaverse are persistence, interactivity and embodiment (Castronova, 2001). Therefore, metaverse can be characterized as a lifelike digital extension of the physical world (Stephenson, 1992) which immerses users in shared and parallel virtual worlds through telepresence (Lemos, 2007). Additionally, the metaverse provides users with opportunities to socialize and interact (Falchuk et al., 2018) while sharing emotions, experiences and culture (Park et al., 2021). Hence, the metaverse renders the creation of virtual communities and social identities feasible and provides users with a sense of belonging and an improved social presence. In addition, as metaverse is the outcome of the conjunction of "virtually-enhanced physical reality" with "physically persistent virtual space," it enables common daily interactions and tasks to move into the virtual world and thus, having the potential to change human societies and culture (Collins, 2008). Its development focuses on the advancements of virtual worlds, augmented reality, mirror worlds and lifelogging while its development axes derive from a spectrum ranging from intimate to external and a spectrum which ranges from augmentation to simulation and focuses on applications and technologies (Choi & Kim, 2017; Smart et al., 2007).

Due to its nature, the adoption and implementation of metaverse in educational settings across all educational levels is becoming more popular. Particularly, within these immersive virtual environments that utilize game elements, students can learn in a more

intriguing, enjoyable and interactive manner while simultaneously enhancing their imagination, their individual and collective intelligence as well as improving their short-term memory (Díaz et al., 2020; Márquez, 2010). Additionally, metaverse allows educators to develop environments which foster affective learning and do away with social and identity barriers (Calongne et al., 2013). Metaverse provides a flexible, diverse, scalable and dynamic learning environment that fosters students' motivation and engagement as it offers more immersive and interactive learning experiences, promotes active communication and collaboration, facilitates the conduct of both synchronous and asynchronous learning and teaching processes (Díaz et al., 2020; Tarouco et al., 2013; Barahona et al., 2016). Moreover, when used in a student-centered manner, the metaverse has the potential to improve students' problem-solving skills and critical thinking (Nurhidayah et al., 2020), enhance their academic performance and learning outcomes (Schaf et al., 2012) as well as increase their comprehension of a subject (Reyes, 2020) and as a result, create dynamic learning environments of higher quality (Tarouco et al., 2013).

1.1. Justification and research objective

Current education is in a process of transformation towards new technological paradigms (Moreno-Guerrero et al., 2021), where students are acquiring new roles (Pozo-Sánchez et al., 2021). This change has been accelerated due to COVID-19 (Daniel, 2020). This pandemic has altered conventional learning environments (Ratten & Jones, 2021). This has produced the generation of new environments, platforms and tools which are able to carry out the teaching and learning process from a ubiquitous perspective (Schneider and Council, 2021). Throughout this generated environment, the digital competence of educational agents has been fundamental in order to follow the training action effectively (Jackman et al., 2021). In this sense, the inclusion of the metaverse in the field of education has been favored by all these conditions (Lee, 2021; López-Belmonte et al., 2022). In short, the metaverse has laid its foundations to project a change in the educational sphere in the coming years (Rospigliosi, 2022). For all these reasons, the need arises to delve into the literature related to the subject from a bibliometric perspective. This discipline will allow the exhaustive study of existing publications, breaking down the documents according to what is intended to be studied. This is based on different study variables such as prolific countries, objectives established in the documents, research methodologies carried out, participants, variables analyzed, instruments used, and findings obtained (Zhao et al., 2021).

The objective of this research is to analyze the existing studies on the metaverse in the field of education in order to establish its theoretical bases and reveal the state of this innovation in the educational field to the scientific community. This will allow the orientation of new studies based on the ones that have already been conducted.

To guide the research towards the achievement of the objective, the following research questions (RQ) that are connected with the variables that are intended to be studied have been formulated. For the formulation of these questions, the considerations of the experts have been taken into account (Tlili et al., 2022):

-RQ1: What have been the most prominent countries in the production of the educational metaverse?

-RQ2: What have been the most relevant objectives in the documents on the educational metaverse?

-RQ3: What research methodologies have been used in studies on the educational metaverse?

-RQ4: What sample of participants has been used in research on the educational metaverse?

-RQ5: What have been the main variables analyzed in studies on the educational metaverse?

-RQ6: What kind of instruments have been used in practise on the educational metaverse?

-RQ7: What have been the main findings analyzed in research on the educational metaverse?

2. Method

2.1. Research design

To achieve the stated objective and answer the different questions, a systematic review of the scientific literature has been carried out based on the guidelines described in Preferred Reporting Items for Systematic Reviews (PRISMA) (Page et al., 2021). Moreover, the analytical model of reported impact studies has been followed to give the work greater scientific rigor (Rodríguez-García et al., 2020; Soler-Costa et al., 2021).

For the literary report, the Web of Science (WoS) and Scopus databases have been used. These are considered as the main databases worldwide, since they bring together publications of impact and scientific relevance (Aksnes & Sivertsen, 2019). In the same way, the guidelines of the experts in this type of study, who have also focused their analysis on WoS and Scopus, have been followed (Zhao et al., 2021). Another of the reasons why these databases have been selected is because they are considered the most relevant that integrate impact publications on educational technology (Lampropoulos et al., 2022; Mystakidis et al., 2022), an aspect directly related to the focus of this study.

In this research, the study variables which have been selected to analyze the documents reported are: the country, the objectives, the methodology, the sample, the variables selected by the researchers, the instruments and the most pertinent findings on the use of metaverse in the field of education.

2.2. Procedure

The research began in January 2022 with the aim of covering all the previous literature throughout all the previous years. The first step of the research was to establish the most pertinent search equation to report the literature on the state-of-the-art. In this case, the equation did not involve any complexity since the study range was well defined. Therefore, only the term "metaverse" was used in the TOPIC metadata, that is title, abstract, and keywords, to collect any document that involved this concept. In turn, the search process was limited to the education categories of WoS, namely Education, Educational Research, and Education Scientific Disciplines as well as to the area of social sciences of Scopus. This search is intended to cover all the scientific literature on the metaverse in education from a holistic perspective. That is, those documents belonging to any educational stage and field of knowledge or focus of study related to education will be taken into account.

The inclusion and exclusion criteria of the reported scientific literature are presented below (table 1).

Table 1

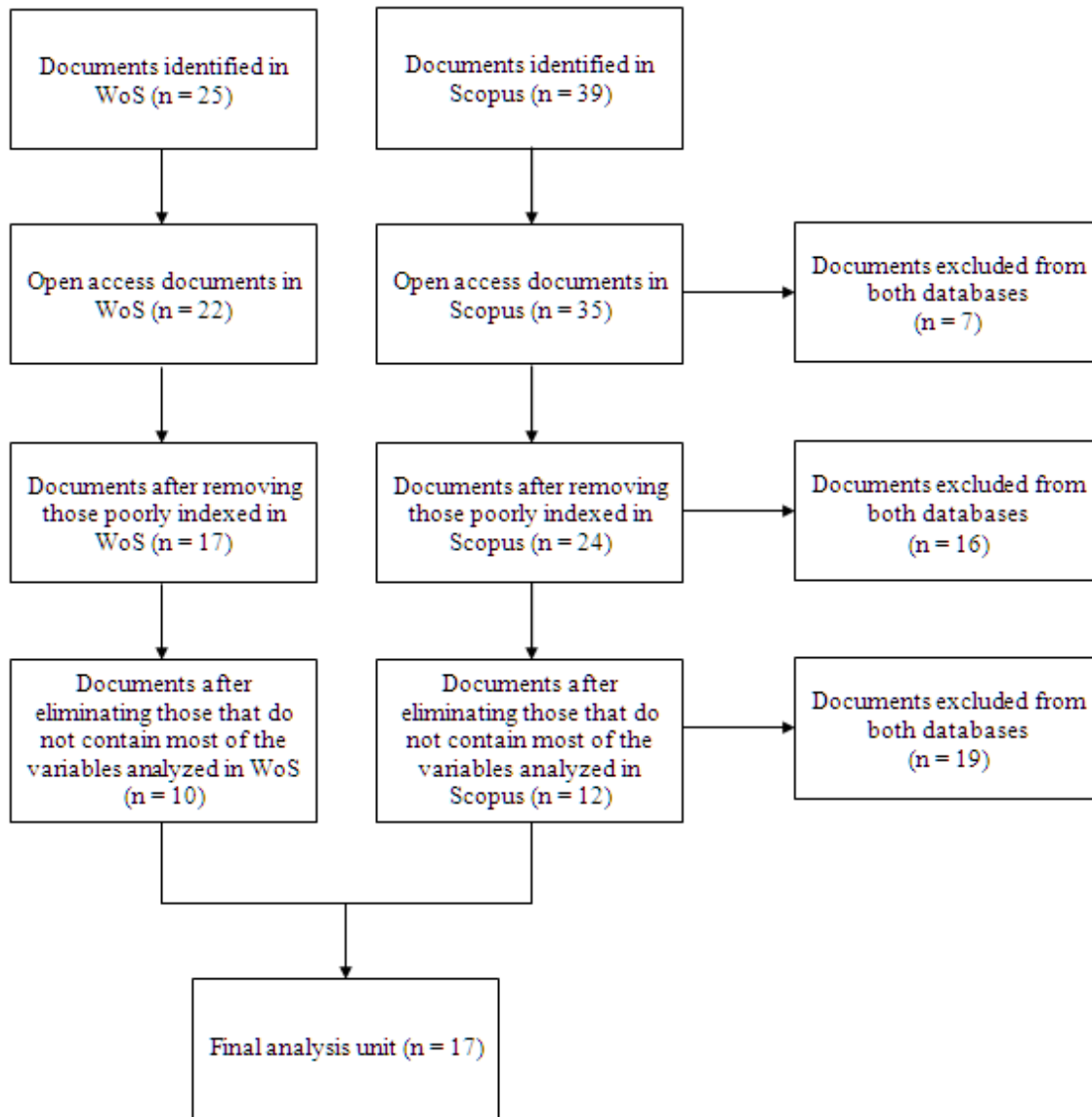
Inclusion and exclusion criteria

Inclusion criteria:	Exclusion criteria:
-Documents on metaverse in the field of education.	-Documents that were not available.
	-Documents poorly indexed.
	-Duplicate documents.
	-Documents that did not contain most of the variables analyzed in this study.

Initially, 25 documents were reported in WoS and 39 in Scopus. This generated a total of 64 scientific publications from both databases. Next, the documentary volume was filtered applying the previously exposed criteria, following the guidelines of the PRISMA protocol for systematic reviews (Figure 1). As inclusion criteria, all documents on the metaverse in the field of education were taken into consideration. This generated an analysis sample of 64 documents (WoS = 25 documents; Scopus = 39 documents). However, to avoid bias in the research, different exclusion criteria were established. Some articles that were not available were not considered (WoS = 22 documents; Scopus = 35 documents). Documents that were poorly indexed (WoS = 5 documents; Scopus = 11 documents), 11 documents that were repeated and all those that did not contain most of the variables analyzed in this study (WoS = 7 documents; Scopus = 12 documents) were eliminated). The definition of these criteria produced a refinement of the documentary report. Therefore, the final unit of analysis was established based on 17 publications.

Figure 1

Flow chart based on the PRISMA protocol



3. Results

The results obtained from the analysis of each of the variables considered in this research will be presented in various subsections in order to facilitate their identification and evaluation. In addition, two tables are provided as an appendix that collect all the variables analyzed from the WoS (Table A) and Scopus (Table B) documents.

3.1. Country

Addressing the first research question about which have been the most outstanding countries in the production of the educational metaverse (RQ1), there are currently two countries (Brazil: 29.4% and Spain: 29.4%) that can be considered pioneers in metaverse research in education. This is the case of Brazil (Arcila, 2014; Díaz et al., 2020; García, 2011a; Reyes, 2020; Tarouco et al., 2013), with five contributions. It is followed by countries such as Spain (Baynat & López, 2020; Díaz et al., 2020; Garrido-Íñigo & Rodríguez-Moreno, 2013; Hadjistassou, 2016; Reyes, 2020) with five contributions,

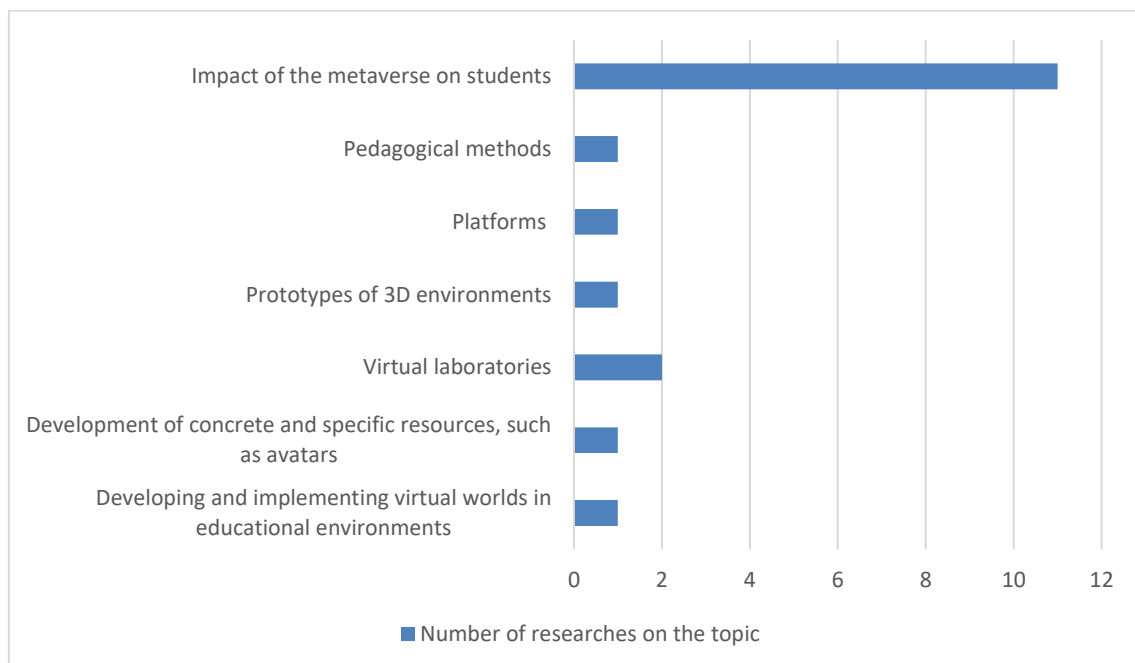
followed by Mexico (Nurhidayah et al., 2020; Park et al., 2021) and Colombia (García, 2011b; Vaca Barahona et al., 2016) with two contributions each.

3.2. Aims

Regarding which have been the most relevant objectives in the documents on the educational metaverse (RQ2), the objectives presented in the various research studies on the metaverse in education are varied. On the one hand, they are about analyzing the problems and challenges that arise when designing, developing and implementing virtual worlds in educational environments (Díaz et al., 2020). On the other hand, they focus on the development of concrete and specific resources, such as avatars (Schlemmer et al., 2009), virtual laboratories (Clark, 2012; Schaf et al., 2012; Tarouco et al., 2013), platforms (García, 2011b), prototypes of 3D environments (Arcila, 2014) or pedagogical methods (Díaz et al., 2020). The rest of the research focuses on identifying the impact of the metaverse on students (figure 2).

Figure 2

Comparative graph of research objectives



3.3. Methodology

In relation to what research methodologies have been used in studies on the educational metaverse (RQ3), the methodology mostly used in research is case studies. Quantitative (Arcila, 2014), qualitative (Vaca Barahona et al., 2016) or mixed (Díaz et al., 2020) approaches were adopted. The type of methodologies followed can be found in the appendix of this manuscript.

3.4. Sample

Addressing the question of what sample of participants has been used in research on the educational metaverse (RQ4), the sample used by the investigators is fewer than 100 participants. This occurs in 10 of the 17 studies analyzed (41.1%). Only in 2 of the 17

studies analyzed (11.7%) does the sample exceed 100 students. In 5 of the 17 studies analyzed, there is no indication of the sample used (29.4%). The samples can be found in the appendix of this document.

3.5. Main variables.

Regarding the question which have been the main variables analyzed in studies on the educational metaverse (RQ5), the variables used in the various studies do not differ much from one another. They focus on the learning outcomes generated by the use of metaverse in teaching and learning processes. Specifically, the various studies focus on reflections on the concepts of presence and telepresence in virtual worlds (Shlemmer et al., 2009), on students' learning outcomes (Nurhidayah et al., 2020), difficulties in implementing the metaverse in training processes (Arcila, 2014), on the time spent on metaverse tasks (Clark, 2012), on the degree of acceptance (Díaz et al., 2020), on motivation (Park et al., 2021) and on communication and interaction among members of the educational community (Vaca Barahona et al., 2016). It should be noted that the remaining studies, at least 10, do not have research objectives. These studies are listed in the appendix at the end of the document.

3.6. Measurement

In relation to the typology of instruments, based on the question which instruments have been used in practice on the educational metaverse (RQ6), the main instruments used for data collection are ad hoc questionnaires (Arcila, 2014; Clark, 2012; Díaz et al., 2020; Hadjistassou, 2016; Reyes, 2020; Schaf et al., 2012; Tarouco et al., 2013) and participant observations in the development of the various tasks applied in the different experiments (García, 2011a; Garrido-Iñigo & Rodríguez-Moreno, 2013; Jaffurs, 2011; Nurhidayah et al., 2020; Park et al., 2021; Schaf et al., 2012; Schlemmer et al., 2009).

3.7. Main Findings.

Finally, responding to what have been the main findings analyzed in the research on the educational metaverse (RQ7), the main results obtained in the various studies analyzed vary among themselves. The appendix at the end of the text contains the most significant results of each of the studies analyzed. Nonetheless, it is true that they have the analysis of the use of metaverse in training processes as a nexus of union. In this sense, Abeles (2007) determined that the use of metaverse in teaching and learning processes will bring about new changes and innovations in both conventional learning and e-learning.

Arcila (2014) stated that students' overall experience in a virtual teaching environment was satisfactory and that their level of acceptance was adequate. Furthermore, it was examined how the virtual environment promoted active participation and collaborative learning. In addition, Schaf et al. (2012) found that meaningful learning, motivation and increased digital competence were fostered. Baynat & López (2020) and Garrido-Iñigo & Rodríguez-Moreno (2013) corroborated what Arcila indicated, but in specific branches of training, such as foreign language learning and music learning (Jaffurs, 2011).

Díaz et al. (2020) observed in their research that the use of the virtual world increased students' engagement, fostering both synchronous and asynchronous learning and teaching processes and provided a flexible, diverse, scalable, and dynamic learning environment. In addition, it increases participation and collaboration (Tarouco et al., 2013). Moreover, Nurhidayah et al. (2020) indicated that it improves learning outcomes while Reyes (2020) observed an increase in the understanding of the subject.

In another novel study, García (2011a) was able to verify that as students became more familiar with and accustomed to the virtual environment, their confidence increased and, as a result, their communication skills improved and new networks were created. In addition, the playful and fun elements helped enhance students' creativity and facilitated the discovery of new possibilities and the creation of a new identity. Finally, above all, the creation of new forms of interaction and communication was feasible (Schlemmer et al., 2009; Vaca Barahona et al., 2016).

In Clark's (2012) study, the experiences were not all positive. Opinions varied depending on students' ability to use and manage the virtual learning environment. That is, their digital competence was a determining factor when evaluating the experience. Along the same lines, García (2011b) postulated. Hadjistassou (2016) further delved into this line, indicating that success in the formative processes depended on the Internet-mediated tools as well as on the different linguistic and cultural values and expectations related to relationship building and interactional dynamics. Park et al. (2021) found no significant differences among the various students who applied the pedagogical method based on the virtual environment when considering the need to offer teaching adjusted to their individual characteristics.

4. Discussion and conclusions

The analysis of the scientific literature has made it possible to verify the revolution that has occurred in the educational field in recent years (Jackman et al., 2021; Moreno-Guerrero et al., 2021; Pozo-Sánchez et al., 2021; Schneider & Council, 2021). This revolution has expanded notably with the transformations produced by the Covid-19 pandemic, producing a change in conventional learning environments (Daniel, 2020; Ratten & Jones, 2021). New learning environments based on virtual platforms and digital tools have been generated to implement the teaching and learning process under the principles of ubiquity (Schneider & Council, 2021). It is this intention of digitalization and virtualization of learning environments that the metaverse acquires special importance (Díaz, 2020; Lee, 2021; Rospigliosi, 2022). The emergence of the first digital realities based on the metaverse and their potential inclusion in the educational field generates the need to analyze the studies available in the educational field to form an analysis of the existing scientific corpus.

Therefore, from the analysis carried out based on the related articles which were from the WoS and Scopus databases under the inclusion criteria of the PRISMA protocol, several inferences have been obtained.

A predominance of publications brought out in Brazil and in Spanish-speaking countries (Spain, Mexico and Colombia) has been confirmed. This fact, reflects a lack of scientific literature by English-speaking and Asian countries, which usually reflect high levels of production in pioneering research in educational contexts. These results at a global level become more meaningful when we compare them with those of other studies which unitarily highlight the contributions of the United States as the main country (Abbate et al., 2022; Tas & Bolat, 2022; Tlili et al., 2022). Despite this, they coincide with the present investigation by highlighting Brazil and Spain as the most prolific countries (Tas & Bolat, 2022; Tlili et al., 2022) and Japan as the main Asian representative (Abbate et al., 2022; Tlili et al. al., 2022).

The research analyzed focuses mainly on case studies and in some cases, quantitative, qualitative and mixed research. Given the predominance of the case study, these pioneering investigations are based on relatively small samples and focus on university students. Only two investigations contain relatively representative samples of more than 100 individuals (Baynat & López, 2020; García, 2011b). These findings coincide with the analysis carried out by Tlili et al. (2022) which highlights that the metaverse is a relatively emerging topic. Almost half of the analyzed documents focused on reviewing the literature and presenting theories. A quarter of the studies used mixed methods, followed by quantitative and qualitative methods.

The main instruments used for data collection are ad hoc questionnaires. (Arcila, 2014; Clark, 2012; Díaz et al., 2020; Hadjistassou, 2016; Reyes, 2020; Schaf et al., 2012; Tarouco et al., 2013) and direct observation during the application of experiences (García, 2011a; Garrido-Iñigo & Rodríguez-Moreno, 2013; Jaffurs, 2011; Nurhidayah et al., 2020; Park et al., 2021; Schaf et al., 2012; Schlemmer et al., 2009). This aspect is supported by the research carried out by Tlili et al., (2022), where it was found that the most mentioned data collection tool was the survey, followed by interviews. Based on the representativeness of the sample, the data collection instruments used and the absence of research in countries historically prolific in the production of pioneering studies, we can confirm that we are facing a preliminary phase in terms of the adoption of the metaverse as a theme of study in educational contexts.

Furthermore, the analyzed investigations present diverse objectives shedding light onto a differentiation between those focused on the impact generated in educational contexts (Abeles, 2007; Baynat & López, 2020; Díaz et al., 2020; García, 2011a; Garrido-Iñigo & Rodríguez-Moreno, 2013; Hadjistassou, 2016; Jaffurs, 2011; Nurhidayah et al., 2020; Park et al., 2021; Reyes, 2020; Vaca Barahona et al., 2016) and the elaboration of metaverse-specific components and platforms (Arcila, 2014; Clark, 2012; García, 2011b; Schaf et al., 2012; Schlemmer et al., 2009; Tarouco et al., 2013). Consequently, we observe a wide margin for improvement for future research that will analyze the multitude of factors involved in educational contexts and in the teaching and learning process in a holistic and transversal way. These results contrast with those obtained by Tlili et al., (2022), who observed three centers of interest: the social aspects of the Metaverse in education (virtual worlds, virtual communities and second lives), the potentials of presence mediated by technology and immersive technologies (metaverse, emerging technologies, virtual environments, telepresence, avatar, augmented reality, mixed reality) and lastly, self-organizing AI-powered virtual learning ecologies (deep learning and simulation). Tas & Bolat (2022) examined the most relevant research objectives related to virtual reality, augmented reality, and Second life within educational spaces. Outside the educational field, the bibliometric investigation of Abbate et al. (2022) found diverse research objectives, from interaction with friends to games and entertainment, work and education as well as invention and commerce. Their work also stands out in other bibliometric studies which focused on the metaverse in the light of artificial intelligence, social networks, virtual reality, and blockchain (Chen & Zhang, 2022; Narin, 2021).

In conclusion, the metaverse in the educational field is a line of study that is at the early stages of research. Digital environments and the use of techno-pedagogical resources in teaching and learning processes are a reality in today's education. Teachers seek an immersion of students in digital learning environments from specific platforms that are

increasingly evolving and that allow a greater degree of student-student and teacher-student interaction. However, the creation of digital learning environments and the search for immersive experiences are not reflected in the proliferation of a significant number of educational experiences carried out in the metaverse. Consequently, a greater volume of research is required to lay the theoretical foundations of an expanding field of study. Additionally, a greater amplitude in the samples used in the experiences brought about in the metaverse in an educational context and a greater variability in its typology that transcends the limits of higher education are required. Finally, a wider variety of instruments used that allow the incorporation of validated questionnaires that improve the reliability of the results obtained from direct observation and/or ad hoc questionnaires.

However, it is pertinent to point out that due to the intrinsic limitations of systematic reviews, the results presented here should be considered with caution. We are facing a research topic that is in a preliminary-exploratory state and thus, there may be significant changes in the research trends proposed in this study during the next few years. Nonetheless, it is essential to carry out a systematic literature review of the main scientific contributions in a subject of study with great potential to ensure an optimal establishment of its theoretical bases and its subsequent adoption as a key subject for the scientific community. This theoretical foundation initiated by the research panorama will allow the metaverse to be brought closer to the educational scenarios in a practical way, after showing the theoretical particularities that can be applied to the teaching methodology.

The prospective of this research focuses on showing researchers and the educational community the current situation on a subject that marks the future of virtual learning environments in both the medium and long term. As reflected in some of the research analyzed, the metaverse has become a reality in some educational cases. More specifically, the broad potential in research into the metaverse in educational context lies in its prospective. Due to the fact the novelty of the field and the metaverse being in a pioneering and exploratory phase, there is still a long way to go for future lines of research that allow scientific literature on the matter to increase. As a result, research is suggested to analyze the inclusion of educational spaces within the metaverse from a holistic perspective. Hence, it is recommended to continue research into this subject in higher education but also in other educational stages such as secondary education, primary education, and professional training. Due to its immersive capacity and its improvements in accessibility, research into the metaverse is especially important for its implementation with students with severe developmental disorders, communication disorders, and autism spectrum disorders. Additionally, the use of the metaverse will make it possible to overcome the barriers created by disabilities of various kinds (auditory, visual, physical or intellectual), providing its users with a high degree of accessibility and adaptability. Therefore, it is recommended to carry out research into the metaverse in students with specific learning needs and educational support to analyze its potential and improve the educational experience of these students.

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Appendices

Table A.

Variables analyzed from the WoS documents

Reference	Country	Aim (s)	Methodology	Sample	Main variables	Measurement	Main Findings
(Schlemmer et al., 2009)	Brazil	To present the telepresence experience which is based on avatars specifically designed to be utilized in virtual environments.	Case study - interviews	15 university students (11 female and 4 male), 20-35 years old with different levels of technological fluency.	Reflections about the concepts of presence and telepresence in virtual worlds.	Interviews	Based on the results, the majority of students maintained their physical identity and features when creating their avatars. The freedom of choice renders new ways of interacting and communicating feasible, while the freedom of movement and interaction helps create more immersive and involving experiences. Moreover, virtual worlds assist students in enhancing their communication skills by creating experiences that derive from the real world while also creating imaginary scenarios that can only take place in virtual environments. Nonetheless, it is essential to ensure a certain privacy level within these entertaining and interactive learning environments.
(Díaz et al., 2020)	Colombia	To identify and analyze the issues and challenges that arise when designing, developing and implementing virtual or metaverse worlds in educational environments when following the Scrum methodology.	Mixed research approach - quantitative analysis	32 university students (first academic semester 2019 of the Faculty of Systems Engineering of University of Cundinamarca)	Students' and teachers' degree of acceptance of the metaverse.	Ad hoc questionnaire and interviews.	Based on the results, the virtual world increased students' engagement, facilitated the conduct of both synchronous and asynchronous learning and teaching processes and provided a flexible, diverse, scalable and dynamic learning environment. Moreover, virtual worlds align with the participatory and collaborative model and allow teachers to implement novel pedagogical approaches.
(Arcila, 2014)	Venezuela	To develop a didactic simulation prototype of	Case study - Qualitative	15 MSc students over	Habits, difficulties	Three part ad hoc	Based on the students' responses, the majority of them neither played role-

		metaverses based on 3D environments in order to reveal participants' acceptance level and to showcase their satisfaction in relation to the use of online tutors and their performance in metaverses.	and quantitative methods	the age of 25 from "Máster Iberoamericano en Educación a Distancia en Entornos Virtuales, impartido por la Universidad de Granada".	phased and experiences in the metaverse.	questionnaire (73 items) regarding students' viewpoints and interviews.	playing games online nor experienced the use of metaverse. Moreover, although a significant number of students had prior experience to online learning, fewer than half of them had worked collaboratively online. Despite some technical difficulties in accessing the virtual environment within Second Life, the students were able to familiarize themselves with it and use its various features. Additionally, the overall students' experience was satisfactory and the acceptance level was adequate. As this specific virtual environment promoted active participation and collaborative learning, it helped towards creating meaningful learning opportunities that foster students' motivation and improve their technological skills,
(García, 2011a)	Spain	To observe the effect of metaverse on the comprehension of the Knowledge Management subject as well as identifying the difficulties that students and teachers may experience during the integration of metaverse into the educational process.	Case study	75 university students from "Universidad Europea de Madrid de las titulaciones de Administración y Dirección de Empresas (ADE) así como las dobles titulaciones de ADE + Investigación y Técnicas de Mercado, ADE		Observations and students' viewpoints based on their personal posts on their blogs.	As students became more familiar with and accustomed to the virtual environment, their confidence increased and as a result, their communication skills were improved and new networks of contacts were created. The playful and fun elements assisted in enhancing students' creativity and facilitated the discovery of new possibilities and the creation of a new identity.

				+ Derecho, ADE + Ingeniería Industrial, ADE + Ingeniería de Telecomunicac iones y ADE + Ingeniería Informática”.		
(Tarouco et al., 2013)	Brazil	To describe how teaching of calculus can be enhanced in both face-to- face and distance classes through the use of virtual learning laboratories.	Case study	University students from Pontifical Catholic University of Rio Grande do Sul (PUCRS).	Ad hoc online/digital questionnaire	Through the prototype virtual laboratory that fosters collaboration, interactivity and dynamic learning situations, higher quality learning which boosts students’ motivation can be attained
(Reyes, 2020)	Mexico	To comprehend middle school students’ viewpoints regarding the impact of implementing teaching strategies that utilize augmented reality applications which were developed using the metaverse software.	Case study	192 first- semester university students (Mathematics Fundamentals course, August- December 2018).	Ad hoc online/digital questionnaire	The developed application significantly helped students’ performance and comprehension of the subject.
(García, 2011b)	Spain	To summarize some of the best practices and to describe the current development stage regarding the application of IT, metaverse and the online collaboration	Case studies based on blended learning environmnets	University students (I could not identify any specific information from the translation).		Although there are still some negative aspects and viewpoints which are mostly associated with technical difficulties, virtual worlds can increase students’ satisfaction and comprehension of the subject.

		platform CityWiki in architecture courses.				
(Vaca Barahona et al., 2016)	Spain	To showcase the potential that virtual learning environments have as an educational tool to promote students' communication, interaction and collaboration.	Qualitative methodology based on systematic observations.	23 university students from "de las carreras de Educación Infantil, de Educación Primaria, de Educación Física y del Máster en Dirección de Marketing de la Universidad de Rovira i Virgili".	Students' communication, interaction and collaboration.	Based on the results, 3D simulation environments help students actively participate in the learning process while simultaneously increasing participants' overall communication and interaction.
(Clark, 2012)	United States	To present a virtual laboratory environment based on Second Life as a means to teach genetics related subjects to undergraduate students.	Case study - Observation - Assessment	5 university students participated at the beginning to provide feedback (fall 2007) and later on 23 first year university students participated in the experiments (spring 2008).	Students' performance on Second Life learning objects and the time spent on tasks.	Ad hoc questionnaire, hands-on experiments and data deriving from sensors. Students' responses regarding the Second Life application were equally divided into positive and negative with a definitive factor being their ability to run the application on their personal devices. Moreover, students' preference towards engaging problem solving activities (e.g. puzzles) contributed towards the positive responses whereas their working in an unfamiliar environment for a short period of time contributed towards the negative ones.
(Schaf et al., 2012)	Brazil	To showcase a virtual environment which was developed to assist in conducting laboratory	Case study		Mixed reality ad hoc experiments.	The prototype application along with its game-like features was met with great acceptance from the students whose motivation also increased and the

exercises and practices in distance learning.

preliminary results showcased positive learning outcomes.

Table B.
Variables analyzed from the Scopus documents

Reference	Country	Aim (s)	Methodology	Sample	Main variables	Measurement	Main Findings
(Park et al., 2021)	Korea	To identify the connection between player type and academic motivation.	Case study - Experiments	91 university students of Kangwon National University.	Academic motivation, content comprehension and enjoyment.	The survey template used was borrowed from the questions in the Science Motivation Questionnaire II (SMQII) developed by Glynn et al. (2011).	No statistical differences were identified among Bartle's four player types and academic motivation, content comprehension and enjoyment. Moreover, educational environments should focus on creating playful experiences, rules and strategies based on the preferences of each player type.
(Nurhidayah et al., 2020)	Indonesia	To enhance students' learning outcomes by applying a systemic approach to problem solving.	Classroom Action Research (CAR) systemic inquiry	35 students from the Vocational School class of Graphic Design at SMK 5 Gowa Makassar.	Students' learning outcomes	Observation and students' academic scores.	The application of systemic approach to problem solving improved students' learning outcomes.
(Reyes, 2020)	Mexico	To comprehend middle school students' viewpoints regarding the impact of implementing teaching strategies that utilize augmented reality applications	Case study	192 first-semester university students (Mathematics Fundamentals		Ad hoc online/digital questionnaire	The developed application significantly helped students' performance and comprehension of the subject.

		which were developed using the metaverse software.		course, August-December 2018).		
(Baynat & López, 2020)	Spain	To present an educational tool which was developed with a view to assisting French university students in preparing for their professional future by simulating a professional situation in the touristic domain and to showcase the didactic possibilities that virtual worlds and the Internet in general can yield.				Digital technologies and resources can help motivate students as they themselves are imbued with technology and bring about several advantages in foreign language teaching and learning activities.
(Díaz et al., 2020)	Colombia	To identify and analyze the issues and challenges that arise when designing, developing and implementing virtual or metaverse worlds in educational environments when following the Scrum methodology.	Mixed research approach - quantitative analysis	32 university students (first academic semester 2019 of the Faculty of Systems Engineering of University of Cundinamarca)	Students' and teachers' degree of acceptance of the metaverse.	Ad hoc questionnaire and interviews. Based on the results, the virtual world increased students' engagement, facilitated the conduct of both synchronous and asynchronous learning and teaching processes and provided a flexible, diverse, scalable and dynamic learning environment. Moreover, virtual worlds align with the participatory and collaborative model and allow teachers to implement novel pedagogical approaches.
(Hadjistassou, 2016)	United states - Greece	To expand the pedagogical inquiry on contradictions by investigating the role of multiple interrelated factors (e.g. semiotic resources, genre discussions, hardware, task-driven activities etc.) in creating new cultural tensions	Case study - Observations	14 university students (13 from the United States and 1 from Greece) and 2 instructors	Data analysis (e.g. virtual exchanges, chat medium, and reflective comments)	Contradictions afforded by virtual exchanges can be contingent on various constructs, on Internet-mediated tools as well as on the different linguistic and cultural values and expectations related to relationship building and interactional dynamics.

		during intercultural exchanges in Second Life.				
(Garrido-Iñigo & Rodríguez-Moreno, 2013)	Spain	To enhance and facilitate the acquisition of French as a second-language for tourism purposes through a virtual environment.	Case study - Experiments	108 university students at Universidad Rey Juan Carlos	Data analysis based on user parameters (e.g. time to complete tasks, scores, groups).	Students' knowledge and comprehension regarding the French language improved and so did their performance.
(Tarouco et al., 2013)	Brazil	To describe how teaching of calculus can be enhanced in both face-to-face and distance classes through the use of virtual learning laboratories.	Case study	University students from Pontifical Catholic University of Rio Grande do Sul (PUCRS).	Ad hoc online/digital questionnaire	Through the prototype virtual laboratory that fosters collaboration, interactivity and dynamic learning situations, higher quality learning which boosts students' motivation can be attained
(Schaf et al., 2012)	Brazil	To showcase a virtual environment which was developed to assist in conducting laboratory exercises and practices in distance learning.	Case study		Mixed reality ad hoc experiments.	The prototype application along with its game-like features was met with great acceptance from the students whose motivation also increased and the preliminary results showcased positive learning outcomes.
(Jaffurs, 2011)	United states	To facilitate the development of a musical identity in a virtual world.	Case study - Experiment	High school students of a music technology course.	5 open ended questions - Interview	Taking into account the advantages and disadvantages of virtual worlds, they can be used as a tool that assists the construction of one's music identity.
(Abeles, 2007)		To identify the main challenges faced by education while transitioning from cohort model (K-16) to an evolving lifelong learning experience as multi-user virtual environments	(Overview)			Since education as a field and the metaverse evolve both technically and culturally, new changes and innovations will be brought about in both conventional learning and e-learning.

(MUVes) or metaverses are
rising.
