Fifteen years of metaverse in Higher Education: A systematic literature review

Cristina Villalonga-Gómez, Eglée Ortega-Fernández and Elena Borau-Boira

Abstract—**The application of the metaverse poses important challenges for the field of education. The aim of this article is to analyze the evolution of the development of the metaverse experiences in Higher Education and thus identify the key aspects of its application as a virtual environment for teaching and learning. To this end, a systematic literature review of articles published in Web of Science and Scopus since 2007 was carried out. In the selection process, 115 articles were identified, of which 34 deal with the metaverse in the field of Higher Education. The analysis shows that the educational metaverse follows a growing trend, since 23.5% of the publications are concentrated in the last year of the analysis and, furthermore, how the metaverse can be analyzed as a virtual learning environment from its three dimensions: technological, pedagogical and content. Educational practices are identified in multiple areas of knowledge, with the educational metaverse being used in the learning of second languages and the simulation of professional environments, both of which are key to HE teaching. The experiences have had mostly positive results, especially due to the immersive potential of the metaverse and the active role of the learner, who becomes the protagonist of the action. Another key element identified in the development of educational strategies in the metaverse is interaction, not only within the techno-educational context, but also with the learning community itself and the communicative and interactive options that arise in this space.**

Index Terms: **Metaverse, Higher Education, learning environments, systematic literature review, virtual reality, augmented reality, educational innovation.**

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I. INTRODUCTION

AFTER the pandemic generated by COVID-19, digitization processes have accelerated exponentially. Our forms of communication have been transformed thanks to technological advances that have brought about the proliferation of social networks, interconnected platforms and multiple applications that provide us with a digital context for human relationships.

The word "metaverse" appears for the first time in the novel Snow Crash, published in 1992 by the writer Neal Stephenson. The author himself in the final acknowledgments of *Snow Crash* points out that the words avatar and metaverse are his inventions, when he decides that the existing terms (such as virtual reality) were too uncomfortable [43].

Mark Zuckerberg, businessperson, founder of Facebook and pioneer in social networks, was the first professional in the field who began to experiment with this immersive universe, even changing the name of Facebook to Meta in 2021, to make his intentions very clear.

Brands, organizations, and institutions are exploring these new fields of interaction: from gaming to art, fashion and advertising, large commercial brands, and all large technology corporations and even the legal sector, are strongly entering the metaverse [9], [43].

In this interesting context, in which great horizons are opening up for the field of training, it is opportune to carry out an analysis of the current scientific literature, in order to know the state of current research and the real scope of the metaverse as a tool for Higher Education.

Thanks to the technological developments that have been promoted since the 1990s, the human figure and the digital environment converge to a greater or lesser extent to achieve a new user experience [85].

The study of this terminology will focus on explaining the immersive possibilities that different technologies can offer, to later focus on its application to the field of learning and higher education.

3D technology is the oldest and is more than 100 years old. William Friese-Greene, responsible for the first cinematographic devices in England, patented it in 1890. It was not until 1922 that *The Power of Love* was projected, the first 3D movie using two simultaneous projectors [54].

The relationship between content and space improves the understanding of the document as an object, and the ability we must perceive volume, distance and depth [60], [23].

From 3D technology, virtual reality has given way, which in turn makes up what are known as virtual worlds, which are scenarios created by technology and that allow an immersive narrative to develop certain tasks, such as video games [50], [52].

The virtualization of our tasks in the real world has made it possible to study the multiple opportunities offered by technology, Nishino *et al*., [55], Mishra and Koehler, [82], Kuru and Zeybek [87]. For example, in 1994, the Universities of North Carolina and the University of California at Berkeley took advantage of the appearance of the Virtual Reality Modeling Language (VRML) to manipulate virtual environments, with the development of 3D classrooms and that have generated changes in perception of the subject and in communication [14].

This tool gave way to new cinematographic and industrial proposals and powerful developments in the world of design and construction, among many other fields. In 2008, the National Academy of Engineering (NAE) pointed to virtual reality as a technological priority worthy of being developed and one of the 14 great challenges for the 21st century [32].

Aznar-Díaz, *et al*. [5] define virtual reality, linked to mobile learning as the technology that, through mobile digital devices integrated into a virtual reality (VR) viewer, allows us to teleport to other virtual spaces.

Cagnina and Poian [10] focused their study on how virtual worlds, such as Second Life, affects business models. These semiotic resources offered a complex learning environment, but more immersive than any other online tool at that time [29], [40]. Nowadays, and almost 15 years later, these opportunities are more tangible with the development of these platforms that try to create new worlds, based 100% on virtuality [16].

These essays have given rise to the metaverse, an acronym composed of 'meta', which comes from the Greek and means "beyond", and 'verse' that refers to "universe", so we speak of a world that is beyond from what we currently know.

The term is defined by the RAE (Real Academia de la Lengua Española) as the representation of scenes or images of objects produced by a computer system, which gives the sensation of its real existence, and its usefulness ranges from the recreational world, through teaching, to much more complex as those developed in the automotive industry.

The metaverse, according to Castronova [12], has three basic characteristics: Interactivity, with a user capable of interacting reciprocally with their peers in the metaverse; Corporeality, which is represented by the avatars in this immersive world that has a presence in the defined space; and Persistence, understood as the constant development of the program even though users are not connected. Mustafa [51] defines it as the network of immersive networked social environments on persistent multi-user platforms.

The models of the metaverse can be established from two central parameters: the technology (from simulation to extension) and the approach (from the user's identity and their power of decision within the environment, to the external world).

The metaverse stands out, therefore, as one more step in the development of technology that has advanced from three-dimensional visuals, through realities and virtual worlds, to a completely immersive experience where users have infinite possibilities that they increasingly resemble the real world [13], [20].

As for the description of these technological tools applied to the areas of learning, it is possible to discern between the different fields of action that exist. According to Meyzan [49] while education is methodological and where the life project is built; learning is flexible and is connected to the acquisition of skills, competencies, and abilities that generate personality traits such as autonomy, responsibility, or emotional stability.

The use of virtual worlds in education is a widely accepted tool worldwide [54]. Recognizing in the same broad capabilities that enhance learning such as the feeling of immersion and presence within the three-dimensional environment added to the possibility of experimenting, exploring and carrying out simulations in real time together with other students by sharing online resources such as videos, audio, texts or images [24], [6].

In this sense, Villalonga-Gómez and Marta-Lazo [76] point out the need for Higher Education institutions to get involved beyond academic instruction, fostering a culture of open and flexible innovation from a critical perspective. These changes in the teaching and learning processes require educational experiences that foster and take advantage of the communicative and creative capacity of students, Zhong and Zheng [78], and here the metaverse plays a fundamental role [17].

The object of study of this work, therefore, focuses on Higher Education, with the aim of delving into research where the metaverse is studied as a learning tool to achieve student attention through its technology and the immersion it offers [27]. For this purpose, a systematic review of the state of the question is conducted, starting from an exploratory approach for the construction of an updated reference framework on research related to the use of the metaverse in teaching and learning processes.

While several studies conducted literature reviews to summarize the findings related to the Metaverse in general and even in education, such as the research by Tliti *et al*., Alfaisal *et al*. [89], López-Belmonte *et al*. [91] or Lin *et al*. [90], no study (to the best of our knowledge) focused on its application in the Higher Education context, where the metaverse is rapidly being adopted. The sudden growth in the interest in HE may stem from a wide range of possibilities – for instance, the virtual space that offers lifelike avatar representations of selves, which may possibly enhance the social aspect of teaching and learning. However, the actual application of the methodology is relatively new and there is a need to examine the state-of-the-art of the current research in the field.

To cover this gap, this study conducts a systematic literature review of the metaverse with Higher Education in mind, while also carrying out the quantitative and qualitative analysis by considering the metaverse as a virtual learning space and proposing an approach based on its three dimensions: technological, pedagogical and content. It then applies both content and bibliometric analysis to reveal the benefits, opportunities and challenges offered by the metaverse as a reformulation of the present teaching methodology.

I. Background

Teaching in the digital environment takes place in spaces in which teachers and students connect through that “telewindow” that is the computer screen [43]. However, is important to select significant, relevant, friendly and, above all, useful and flexible digital tools, to facilitate this learning.

The appropriation of these technologies is especially relevant for teachers, since it is frequently mentioned that teachers are one of the most important influences both for the use of ICT in the teaching-learning process and for the use of these technologies both inside and outside the classroom by students [3], [25]. The importance of the integration of teaching technologies is indisputable. The metaverse, in this sense, poses a challenge that goes beyond the "classroom without walls", seeking a totally immersive, interactive, and personalized experience, in which the learner is really the protagonist of the process. In addition, the movement towards the virtual world as a viable teaching and learning environment seems unstoppable [36], [18].

In today's Information and Communication Society there is an attentional crisis, becoming our scarcest resource. We need to face this natural tendency to distraction, and immerse them in a rich, stimulating and absorbing educational experience, where they themselves feel the center of learning [39].

Unlike traditional education, an immersive environment brings children, adolescents, and young people closer to knowledge in a different way, motivating learning through playful activities such as mini-games, interactive lessons, and experiential experiments, maintaining in this way, the attention of the students [15].

With the arrival of the metaverses or 3D virtual worlds - exemplified in Spain and other countries by the popular and media success of Second Life-, as Rymaszewki [70] points out, a world full of training possibilities opens through the simulation of spaces and experiences that affects multiple frames of reference.

In this sense, meaningful learning is achieved by what the user does and not by what the software does, beyond traditional face-to-face learning in the classroom. [11], [62].

This new digital ecosystem, although it brings with it many questions due to being in the process of study and evolution, opens the door to exciting possibilities. According to Tili *et al*. [73] the advent of immersive technologies, including Virtual Reality (VR), Mixed Reality (MR), Augmented Reality (AR) and Extended Reality (XR) has further promoted metaverses in various educational applications: free courses in the metaverse using OpenSim, AR and mobile learning to teach math, or the world types in the educational metaverse: survival, maze, multiple choice, run/jump, and escape room. The findings showed that student-learning outcomes could be improved [28], [65], [59].

The practice in metaverses seeks interaction in a virtual environment from the point of view of simulation, using a platform little known to the students and seeking the extension of their tangible reality [14].

In fact, the strong visual load and richness of these worlds and the fact that users can manage their own digital graphic representation (or avatar) through three-dimensional space are just some of the peculiarities that provide their users with a different experience than traditional educational settings. This immersion and interaction allow teachers and students to explore new approaches in learning processes, favoring collaboration and thus efficiency and greater adaptability [69].

The incorporation of emerging technologies continues to open opportunities for progress and improvement, in accordance with Dimitriadou & Lanitis (2023) [21], but also challenges such as security, digital identity, teacher training or the humanization of the metaverse environment itself.

According to Raso [67], the impact of technologies calls for standards developed in the highest international consensus, to generate practical criteria for application in our environment, especially within the framework of the metaverse.

Arribas [4] affirms that lawyers specialized in digital law are called to take on this great opportunity and play an important role in supporting the innovation of the organization they advise in this new environment. Continuing with the challenges posed by the metaverse, Ortega-Rodríguez [57] and Peña de San Antonio [63] highlight the need to build a culture or set of basic norms and values to communicate, work and be in the metaverse, but above all to safeguard the identity of users.

Returning to Raso [67], he indicates that science fiction, expressed in Stephenson's novel, is becoming "plain" science, with such disorienting speed in the face of the special impact that the new virtuality will pose for the always-complex phenomenon of labor relations.

Considering the above and continuing with the metaverse as a training resource, it can be said that it challenges the *status quo* of traditional learning, in terms of the combination of technological innovation, the usefulness of content and the usability of technological platforms.

The educational tool, therefore, should be as attractive as possible so that we fully immerse ourselves in it, managing to attract our attention and all our senses, but establishing an ethical code, a culture and protecting the identity of users. In 2008, the National Academy of Engineering (NAE) identified virtual reality as one of the 14 great challenges for the 21st century, being a technological priority worthy of being developed [32].

In fact, learning "by doing" is considered one of the most appropriate ways to teach and train. Humans are trained most effectively when learning becomes a process of active construction of knowledge and interaction between peers [44].

In this way, the student assumes the learning process as their own experience [26]. The immersive reality, in this sense, improves the expectations and interest of the students and supposes an increase in the acquired competences [19].

The personalization of learning that is achieved in the 3D World is obtained as a resident of the metaverse by using its resources. From a basic knowledge of the movement and customization of our avatars, the exploration of its possibilities is endless. In this way, the immersive learning of Web 3.0 allows the development of significant innovative and potentially exploitable learning for technical and technological training programs where learning is done [71].

However, the interest of simulation is not, as is often thought, to replace human experience or reality (the perspective of substitution defended by authors such as Baudrillard [7] or Negroponte [54], but to allow the formulation, exploration and learning of many hypotheses and new mental, emotional and experiential models [66].

The metaverses represent, therefore, a decisive step in the creation of fun, participatory, collaborative, and visually attractive educational spaces. Among others, it may help learners improve both their speaking and their listening skills [22], [75].

In this way, tools such as creativity and artistic ability with the construction of your stage and the capture of different objects available on the 3D platform are essential. As well as the interaction with other residents of the metaverse in the form of chat, audio, video and with classmates thanks to the meetings scheduled by the instructor, complementing the use of practical utilities such as information reception and location.

According to Pérez-Escoda, *et al*. [64], Digital Literacy is a fundamental starting point, also new skills thanks to elements such as motivation, creativity, interest, connection, autonomy, relationship, learning and satisfaction are essential [2].

II. Methodology

To analyze the scientific research published on the application of the metaverse in the field of education and, specifically, in Higher Education, a systematic literature review has been carried out. As this is an emerging field of research (that of the metaverse), this research is based on an exploratory approach.

Thus, the aim of the analysis is to build an updated framework of reference on the state of the art of research related to the use of the metaverse in teaching and learning processes at the university.

The study part of a systematic approach that focuses on scientific rigor in the phases of search, evaluation, analysis and synthesis (Grant & Booth, 2009) [88]. The main objective is to assess the current state of the matter on a novel topic that is constantly developing in our current society. Therefore, it is sensitive to investigations such as those presented due to the scientific interest that they provide as a systematic review. This frame of reference will allow an impulse of knowledge to delimit future lines of research by identifying trends, strengths and weaknesses in published studies by Shahnazi & Afifi, 2017 [84] and García-Orosa, *et al.*, 2023 [28].

To this end, the model proposed by Kitchenham [80], [81] was used, based on three phases: (1) Planning; (2) Conducting; and (3) Reporting. Research by Laine and Lindberg [92], Mastan *et al*. [93] or Huber and Hagel. [94] has applied Kitchenham's systematic literature review model and inspired the research carried out in the present study.

A. Planning

1) Identification of the need for a review

The development of experiences in the metaverse is presented as one of the trends in the digital sphere that may become more important in the coming years [77]. Within these experiences, it is interesting to analyze the metaverse as a virtual learning environment and to identify its educational potential for Higher Education students.

On the other hand, an operational and precise definition of the construct has a determining influence on the subsequent obtaining of the different types of evidence, helps to specify the most representative behaviors of the variable being measured and facilitates the process of constructing items.

In order to carry out an operational definition of the variable we are interested in measuring, it is essential to carry out an exhaustive review of the literature published on the subject in order to delimit the variable to be measured and consider all the relevant dimensions of the same [48].

The aim of the review is to build a framework that allows us to better understand how the metaverse has been applied in general and, specifically, in the Higher Education, and thus identify the key elements for the design of educational experiences in this digital context.

2) Specifying the Research Questions

The research questions addressed by this study are:

-- RQ1. How often do metaverse studies emerge?

-- RQ2. What objects of study and methodologies are being researched in the virtual context of the metaverse?

-- RQ3. Which countries are leading metaverse research?

-- RQ4. Of the published research on the metaverse, which volume refers specifically to learning experiences in Higher Education?

-- RQ5. What types of topics and content are most common in educational experiences in the metaverse?

-- RQ6. What digital environments and technological platforms are being used in university educational experiences in the metaverse?

-- RQ7. What pedagogical elements should be considered in the design of learning experiences in the metaverse?

3) Review protocol

The review protocol developed is aimed at systematically identifying and analyzing research on the object of study. The bibliographic search focused on two scientific databases: Web of Science (WoS) and Scopus, applying the following search strategy. To identify indexed scientific articles published on metaverse, a first search was carried out with the word "metaverse" in text, abstract and keywords.

In a first phase, a search in Spanish using the keyword "metaverse" was also included, but the search results were very limited (two scientific articles in WoS and one in Scopus). It was decided to discard them as they could not form a significant corpus in this language. The inclusion criteria applied in the selection process of published indexed articles are specified in the implementation section.

B. Conducting

The implementation of the review protocol described in the previous section was carried out in three phases, detailed in the following sections, following Kitchenham's [80], [81] model:

1) Identification of research

In the first phase of the research, carried out in May 2022, the articles under review were identified. To do this, the reference sources were first determined, selecting two of the

main world databases for bibliographic references and citations of periodicals in the area of Social Sciences: Web of Science (Clarivate Analytics) and Scopus (Elsevier), through the online search available on the website of the Spanish Foundation for Science and Technology (FECYT). The search criteria were then determined, as follows:

1) Search for the keyword "metaverse". As this is an emerging field of research, it was decided to carry out a generic search with the keyword "metaverse" in English, selecting the scientific articles that include it in the title, abstract or keywords. Applying the first search, 504 publications were found in WoS and 351 in Scopus, i.e. a total of 855 indexed publications.
2) Period of publication: Regarding the year of publication, all publications are selected, from 2000 to 2021. Publications in 2022 are discarded, as they are still in progress at the time of the search and the analysis would be incomplete. Of the 855 publications containing the keyword "metaverse", 299 correspond to the period January-May 2022, the rest, a total of 556, are earlier (335 in WoS and 221 in Scopus).
3) Type of document: Only peer-reviewed journals have been selected for the analysis, and other types (e.g. conference, book, book chapter, conference review, etc.) have been discarded. Applying this filter, a total of 324 articles were found (250 WoS and 74 Scopus).

In order to refine the results, an additional criterion has been applied, which is that, with respect to the results extracted from WoS, a large volume of them belong to the Korean Journal Database (KCI) (178 publications). In order not to condition the results geographically, it was decided to discard the references from this database. It is recommended that a detailed study be carried out in future research on the same subject.

Once the above criteria had been applied, the final sample for the review of the scientific literature consisted of a total of 112 articles, 38 from WoS, 40 from Scopus and 34 works that are in both (duplicates). In order to limit the sample of articles to the object of study, a content analysis of all the abstracts (112) was carried out and only those related to the field of Higher Education (34) were extracted. Finally, a qualitative content analysis of the latter was executed. A summary of the final sample can be found in Table 1.

The Figure 1 shows the summary of the systematized review process:

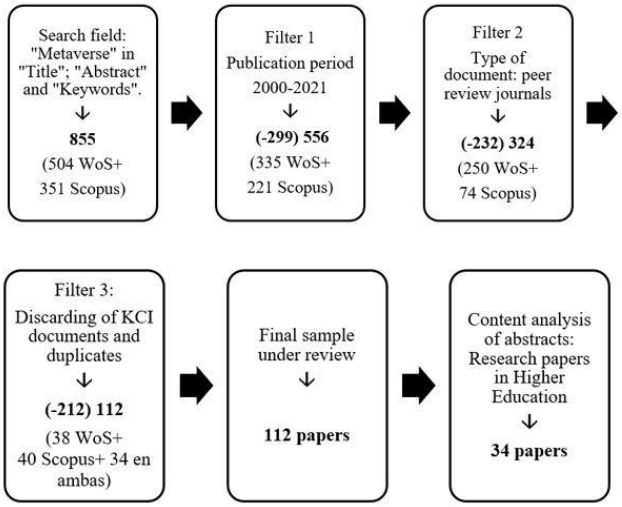

Fig. 1. Synthesis of the review process for the selection of target scientific articles for the systematic review of metaverse literature. Source: Prepared by the authors.

2) Selection of primary studies and quality assessment

For the final selection of articles to be explored, the titles and abstracts of the 112 articles downloaded from the above-mentioned databases were analyzed in detail. In order to assess the quality of the articles and their suitability according to the research questions posed, an analysis of the contents of the titles and abstracts of all articles was carried out in two rounds and by two different researchers.

After this review, a first content analysis was executed, answering questions RQ1, RQ2 and RQ3. Finally, articles dealing with research in the field of Higher Education, i.e. 34 articles, were extracted to answer questions RQ4, RQ5, RQ6 and RQ7, through a qualitative content analysis.

3) Data extraction and synthesis

The aim in this phase of the research is to analyze systematically the selected studies in order to answer the research questions posed. To this end, categories of analysis have been established at two levels.

On the one hand, categories referring to the descriptive characteristics of the selected studies: authors, year of publication, country of origin and publication. On the other hand, the categories referring to the content: title; key words; research methodology (quantitative/qualitative); main themes on which the experience in the metaverse is based and learning experiences in the field of Higher Education. Once the categories of analysis had been defined, two researchers carried out the content analysis and synthesis of the data by means of a form. In the case of keyword analysis, the Clauset-Newman-Moore algorithm [17] was applied. By means of this algorithm, the most common thematic categories in metaverse studies and their relationship were identified.

Regarding the analysis of the articles related to Higher Education, the researchers applied a qualitative content analysis based on constant comparison analysis, focusing on three stages: (1) Open coding: identification of content segments and units; (2) Axial coding: grouping of codes into categories; and (3) Selective coding: categorization by theme. This method facilitates the identification of key concepts through

comparative and systematic analysis of the data and assessment of data saturation [54].

Ref.	Year	Journal	Keywords
[23]	2007	*International Journal of Performance Arts and Digital Media*	Embodiment; metadata; non-human body; web 2.0; UGC (user generated contents); virtual worlds
[16]	2009	*Innovate: Journal of Online Education*	Biological Sciences; data analysis; experiments; genetics; Higher Education; online courses; pilot projects; science education; undergraduate students
[43]	2010	*Online Worlds: Convergence of the Real and the Virtual*	Virtual World; information space; online service provider; Internet World Stat; online information service
[77]	2010	*Sistemi Intelligenti*	Enhancement; metaverse; plasticity; second-order; cybernetics
[40]	2011	*Social Semiotics*	Second Life®;religion; places of worship; virtual participant; observation semiotics
[9]	2011	*Journal of Brand Management*	Branding; education; Second Life; virtual worlds
[22]	2011	*International Journal of Technology Enhanced Learning*	Language; learning; Second Life; tandem learning; virtual worlds
[99] [100] [101] [102] [103] [104]	2012	*Virtual Worlds and Metaverse Platforms: New Communication and Identity Paradigms*	NA
[55]	2012	*Frontiers in Artificial Intelligence and Applications*	E-learning; learning adaptability; learning preferences; metaverse; synchronous learning
[30]	2013	*Expert Systems with Applications*	Expert systems; artificial intelligence; OpenSim; Sloodle; ARIMA
[44]	2013	*Advances in Intelligent Systems and Computing*	E-learning education; metaverse; Moodle; OpenSim; Open Simulator; practices; practices and employment; service of professional insertion; SIPPES loodle; University of Salamanca; USALVirtual
[68]	2014	*Pixel-Bit, Revista de Medios y Educación*	Augmented reality; mobile learning; mathematics; innovation; learning strategies.
[47]	2014	*Journal of Cases on Information Technology*	Continuous evaluation; educational videos; Metaverses; Open Sims; Second Life; seminars
[29]	2015	*Interactive Learning Environments*	Virtual reality; virtual heritage; presence; realism; immersion
[32]	2015	*International Journal of Web-Based Learning and Teaching Technologies*	Contradictions; intercultural exchanges; Second Life; social virtualities
[65]	2016	*Tercio Creciente*	Second Life; metaverse; machiminas; Second Life; creation
[34]	2017	*Revista Educación en Ingeniería*	Metaverse; 3D scenarios; mechanical physics; OpenSim
[66]	2017	*Information Technologies and Learning Tools*	Synthetic learning environment; artificial environments; virtualization; educational activity; simulation; modeling; metaverse
[20]	2020	*International Journal of Emerging Technologies in Learning*	Avatar; digital tools; emerging technologies; metaverse; Moodle, open simulator; singularity
[95]	2021	*Procedia Computer Science*	Eye blinking system; metaverse; Second Life; active learning; e-learning
[96]	2021	*Journal of Educational Evaluation for Helath Professions*	Augmented reality; communication; educational personnel; medical education; virtual reality
[97]	2021	*Journal of the International network for Korean Language and Culture*	Metaverse; metaverse platform; virtual reality; non-face-to-face education
[51]	2021	*Sensors*	Virtual avatar; virtual human; virtual character; embodied conversational agent; social interaction, emphaty
[42]	2021	*Sustainable Energy Technologies and Assessments*	Metaverse; metaverse-based multi-agent double delay deep deterministic policy gradient algorithm; Proton exchange membrane fuel cell (PEMFC); power coordination management method; Distributed deep reinforcement learning
[59]	2021	*Sustainability*	Gamification; education; Game-Based Learning
[33]	2021	*Human-centric Computing and Information Sciences*	Affordances Character; animation; climbing structures; Metaverses; motor performance; performances evaluation; real-time sport;climbing structure-based
[72]	2021	*IEEE Access*	Aircraft maintenance education; Boeing-737; deep learning; industry 40; metaverse; mixed reality; neuro-symbolic AI; smart glasses; speech recognition; transformer
[8]	2020	*Synergies Europe*	Virtual Worlds; Computer-Aided Instruction; Virtual Learning Environment
[71]	2021	*Sensors*	Aircraft maintenance education; Boeing 737; deep learning; Industry 4.0; metaverse; mixed reality (MR); smart maintenance; speech interaction

Table. 2. Summary of the selected papers.

III. RESULTS

A. Results of the quantitative analysis of the indexed articles that make up the "metaverse"

The results indicate that interest in the metaverse continues

to grow, in line with the papers published in this regard: a total of 855 indexed publications include "metaverse" in the title, abstract or keywords, 504 scientific articles in WoS and 351 in Scopus.

Another fact that supports the growing interest that the metaverse arouses in the scientific community is the temporality of its production, with a total of 22 publications in 2021 alone, 14 more than the previous year. The year 2022 has not been included because it is not over yet, although only from January to May 2022 there are already 299 indexed publications. With respect to the country with the most scientific production, the United States is in the lead, with 25% of the total, followed by the United Kingdom with 16%, Korea with 14%, Brazil with 11% and Spain with 9%.

In the evaluation phase, the title, abstract and method to apply a series of exclusion criteria –adequacy and quality– have been checked. In the first place, we contrast that each document responds to the object of study that focuses the review, discarding those articles that do not deal with the relationship between artificial intelligence and the field of communication.

It has also been reviewed that the articles meet the standards of scientific quality, although it is assumed by the fact that they are published in journals indexed in the indicated databases. The final sample consists of 112 documents, which were categorized and, in some cases, a single investigation was adjusted to two categories at the same time.

Regarding the results obtained on the most common thematic categories in studies on the metaverse, which have been extracted from the content analysis, it has been found that the most studied is the one referring to ICT Tools and digital design with 86 of the articles, such as computer tools to synthesize the entire designer process, Mateo-Girona, *et al*. [48], [24].

The second most studied category is that referring to education and learning, with 46 papers in total, of which 34 refer to the convenience of the metaverse to encourage the field of higher education, specifically [32], [2].

In this category of education and learning, eight articles were not taken into account because they were outside the object of study (higher education); they focus their contents on studies at other levels, research in the field of religion and beliefs, journalism, narrative, legal aspects and heritage.

The fields of Finance, business models and real estate add up to 28 titles, while analysis of gaming and the ludic model in the metaverse reach 26 publications. Finally, those referring to the world of marketing add up to 9 papers.

Fig. 2. Results by categories after content analysis. Source: Prepared by the authors.

When making the review, the country from which the research was conducted and published was also taken into account. In general, the United States tops the list with 25% of publications, followed by the United Kingdom with 16%, then South Korea with 14%, Brazil with 14%, Spain with 9% and Turkey with 8%. In the list of other countries, we find Mexico, Taiwan, Ukraine, Denmark, Indonesia, Greece, Canada, Serbia, Russia, Israel and Finland; each of them with a single investigation, which, as it was not representative, was added to the Others block.

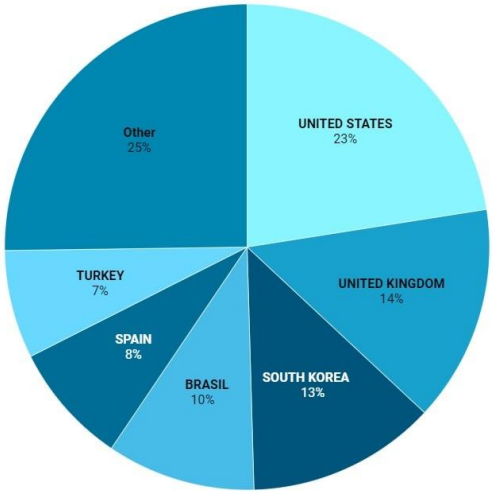

Fig.3. Results by country of the publications. Source: Prepared by the authors.

By focusing on the countries that stand out in the number of publications only on Higher Education, we find that Spain and Korea are the ones with the largest number of investigations in this area.

The years of publication are shown with few publications between 2000 and 2007, with specific years where no study on the metaverse was developed (2000, 2002, 2003 and 2004), tending to increase interest from the year 2005 slightly and great push between 2008 and 2013, to mark a decline in 2014, and resume strongly in 2015, and continue the growth of studies until 2020. There is no exponential evolution but in 2021 production increases notably.

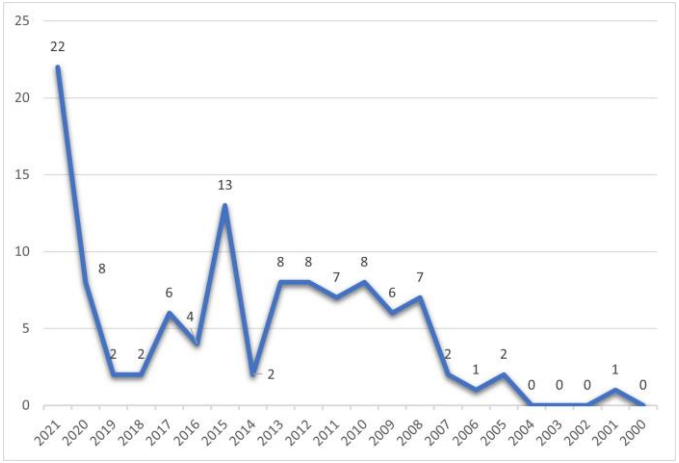

Fig.4. Results by years of publications. Source: Prepared by the authors.

From the selection of articles referring to the metaverse, a total of 517 keywords emerge that accompany the various investigations that have been analyzed. To appreciate their relationships graphically, we have used grouping by words, replicating the Clauset *et al*. [17] with the NODE XL tool, to

obtain as a result the graphic representation of how the words are interrelated.

The largest circles show the words that are repeated the most, while the ones with the most association due to their use and meaning are grouped by color. The word metaverse, virtual, digital, reality, second life, education, 3D and augmented can be highlighted.

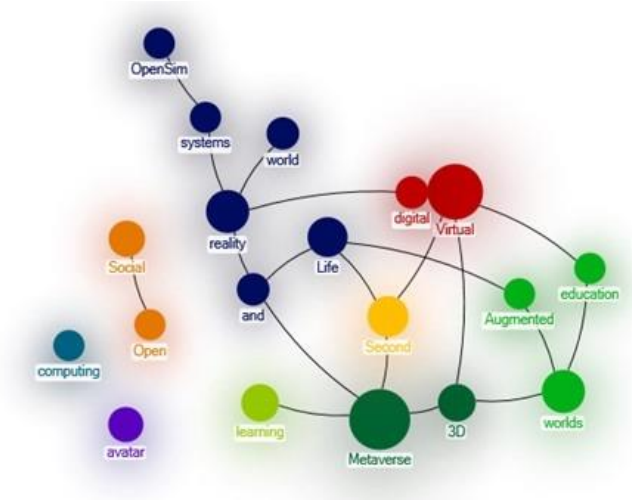

Fig.5. Graphic representation of the keywords. Source: Prepared by the authors using NODE XL tool.

Likewise, by crossing more data on the country of origin and the most used methodology, we have delimited, in a basic way, qualitative methodology and quantitative methodology, according to what predominated more in the investigations, crossing this information with the country where the study came from.

The result shows us where there is a greater number of publications, highlighting the United States, United Kingdom, and Spain, with investigations in which both methodologies stand out. Researchers in South Korea they tend to focus on a more quantitative methodology, while Brazilian researchers opts for more qualitative research.

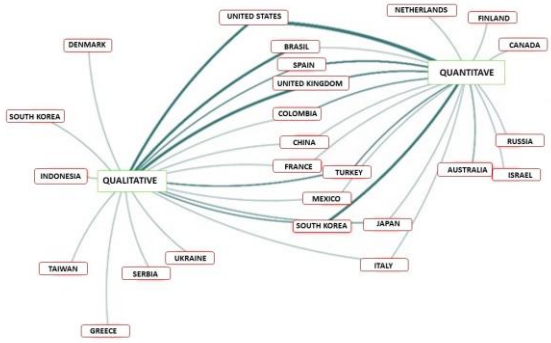

Fig.6. Representation of the most used methodologies in the different countries. Source: Prepared by the authors using NODE XL tool.

B. Results of the qualitative content analysis of the articles referring to research in Higher Education

As indicated above, the number of articles subject to qualitative content analysis is 34 (articles showing research linked to the field of Higher Education). The analysis yields result from 2007 to 2021 (limit for this systematic literature review), a year in which an increase in the number of publications is identified (23.5% of the total). In terms of the geographical origin of the research, there is research from Brazil, China, Colombia, Greece, Italy, Japan, South Korea, Mexico, the Netherlands, Spain, Ukraine, the United Kingdom and the United States, with Spain and South Korea being the countries with the most publications on university educational metaverse (17.64% each). Regarding the type of research, 50% of the research is quantitative and the other 50% qualitative.

As for the content analysis itself, once the selective coding was carried out, the following categories and subcategories of analysis were established. For this, considering the metaverse as an educational virtual space, the TPACK framework (Technological, Pedagogical Content Knowledge) [55], [79] has been taken as a reference.

This methodology integrates technology to the same degree of importance as disciplinary and pedagogical content, and its immersion must be closely related to this knowledge. In this way, the three dimensions (technological, disciplinary and pedagogical) are considered, and an additional category is added to differentiate the types of approach to research in the papers analyzed. Thus, the categories of analysis are:

-- C1: Approach to research:
  - C1.S1.: Theoretical educational research
  - C1.S2.: Practical educational experience
-- C2: Technological dimension:
  - C2.S1.: Description of the virtual context
  - C2.S2.: Technological platform
-- C3: Discuplinary Dimesion:
  - C3.S1.: Area of knowledge
  - C3.S2.: Topic
-- C4: Pedagogical dimension:
  - C4.S1.: Teaching modality.
  - C4.S2.: Learning activity.
  - C4.S3.: Methodologies.

The main results for each of the categories of analysis are shown below.

1) C1. Research approach: theoretical analyses and practical experiences (C1.S1.-C1.S2.)

Two subcategories corresponding to the research approach are identified in the articles analyzed. On the one hand, 44.1% of the analyzed articles correspond to theoretical research on the metaverse in the field of education, with the main themes being the technological development of metaverse platforms, e.g. [61], [68], [74]; cultural differences and identity management (avatars) in the metaverse, e.g. [29], [58], [38]; cognitive response and opportunities and challenges of the metaverse for education, e.g. [37], [53], [95], [96]. On the other hand, 55.88% of the research analyses practical educational experiences developed in the metaverse, e.g. [8], [9], [35], [21], [27], [31], [42], [45], [98]).

2) C2. Technological dimension: virtual context and platforms (C2.S1.-C2.S2)

All the research analyzed provides a description of the technological context. Of particular note is the article by Kye *et*

al. [39], in which the authors define and categorize the educational application of the different types of metaverse: augmented reality, lifelogging, mirror world, and virtual reality.

The articles discuss 3D immersive environment; virtual worlds and digital virtual worlds; artificial and synthetic environment; open metaverse; multi-user virtual environment (MUVE) and metaverse for mobile devices.

Within the technological dimension, the research analyzed refers to specific metaverse platforms, e.g. [33]. The platform with the most educational experiences is Second Life, as 44.1% of the total number of articles refer to experiences in this environment and of the practical educational experiences (C1.S2.), they represent 73.68%, e.g. [16], [62]. Another of the most widely used platforms is Open Sim -e.g. [32], [28]- and Open Wonderland. Recent research identifies platforms such as Eduverse, Gather, Zepeto and Roblox.

One of the platforms cited is Foldit, described as a crowdsourcing computer game that allows contributions to scientific research. Moreover, the research analysed includes the free and open-source platform Open Cobalt Alpha for building, accessing and sharing virtual workspaces for research and education, a project of Duke University [41].

In terms of platforms, some of the experiences described also link their use to LMS (Learning Management Systems) platforms, such as Moodle, e.g. [2]. In other words, the experience does not only include the metaverse platform, but combines it with this other digital learning environment.

3) C3. Disciplinary dimension: area of knowledge and topic (C3.S1.-C3.S2.)

With regard to the disciplinary context, various areas of knowledge and subjects are identified in the research analyzed. For the analysis, the categorization of areas of knowledge established by the National Agency for Quality Assessment and Accreditation of University Education in Spain is taken as a reference: (1) Sciences; (2) Health Sciences; (3) Engineering and Architecture; (4) Social and Legal Sciences; and (5) Arts and Humanities.

The area with the highest number of educational metaverse studies in the field of Higher Education is Social and Legal Sciences, which accounts for 52.94% of the total number of publications. Within this area, the most common topics are educational research (26.47%); followed by research in communication and marketing (11.76%); research in second language teaching (8.82%); the professional field (5.88%) and research in the field of sociology.

Another area with more publications is the area of health sciences (20.58%), mainly with research in the field of psychology (cognition and perception in the context of the metaverse). Regarding the other areas, 17.64% corresponds to research in the field of Engineering (technology applied to the environment), 5.88% to Art and Humanities (artistic creation and narrative) and, finally, 2.94% to the field of sciences (mathematics).

4) C4. Pedagogical dimension: modality, type of activity and methodologies

Most of the articles analyzed link the use of the educational metaverse to online, hybrid and mobile learning (88.23%), and only 11.76% link the use of the metaverse to an extension of the face-to-face (physical) classroom.

Regarding the type of activities described, they are practical and interactive. Specifically, they are described as laboratories, seminars or experimentation spaces (simulation). Regarding the teaching methodologies applied, the most common is gamification, i.e. the application of typical elements of game playing (e.g. point scoring, competition with others, rules of play) to other areas of activity, in this case, Higher Education, e.g. [21], [59].

Related to this, the research analyzed also speaks of the application of Problem-based learning, PBL, e.g. [35], that is, an instructional learner-centered approach that empowers learners to conduct research, integrate theory and practice, and apply knowledge and skills to develop a viable solution to a defined problem [81].

Within the pedagogical dimension, the analyzed research identifies some key aspects of the educational potential of the metaverse for Higher Education:

-- Communication, interaction and participation: the metaverse context facilitates communication between learners and the creation of virtual communities, which is based on the networked learning culture. A social environment invites conversation even beyond class hours. It is therefore not only about teaching and learning activities, but also about holistic educational activities such as learning, communication and empathy.

-- Learning by doing: to really take advantage of the educational potential of the metaverse, lessons need to be designed specifically for this environment, with problems (with a predefined mission) or cooperative and creative project work. It does not make sense to replicate the same strategies that could be carried out in an LMS platform, with the tools that integrate these environments (forums, videoconferences, content and reading repository, etc.), but it does make sense to combine the use of both virtual environments.

-- Self-directed, autonomous and active learning: It is possible to experience self-directed learning based on the autonomy of the spatial movement of the metaverse. In this sense, the role of the teacher in promoting learner autonomy is essential for the design of motivating and innovative experiences that facilitate exploration.

-- Immersive learning and simulation: the metaverse make it possible to create virtual "new places", suitable for simulation, with a high degree of immersion through virtualization. For example, it allows the recreation of real-world situations such as (e.g. conducting professional interviews or recreating work environments; use of concrete technology, such as aircraft maintenance through digital twins, etc.). In a way, it has the ability to apply theoretical principles to real-life scenarios.

In the same way, some limitations are highlighted in the analyzed articles, such as:

-- Weaker social connections and the possibility of privacy violations or misuse of student data (lack of regulation).

-- There is a lack of theoretical and pedagogical models for the educational metaverse.

-- There is a strong technological dependence (5G).

IV. DISCUSSION

This section has been structured taking as a reference the research questions posed (RQ1-RQ7) and the results obtained in the development of the systematic literature review. As stated in the introduction, in addition, some systematic literature reviews on the metaverse [50] and only one bibliometric review and analysis focused on the application of the metaverse in education [73] have been identified.

Thus, this discussion also compares the results obtained in this research with those of previous studies, but with a focus on the application of the metaverse in Higher Education.

The concept of "metaverse" was born in 1992, but it was not until 2007 that the first research on metaverse in the field of education was published in a journal indexed in WoS and Scopus [73], and in the field of Higher Education.

In the analysis carried out on the 112 selected researches [Fig. 1], we identified studies on metaverse since 2001 (research on Gaming, communication and marketing, finance and real state, ITC and digital design [Fig. 2]), with a geographical distribution centred on USA, UK, South Korea, Brazil, Spain, Colombia, Turkey, etc. [Fig.3].

A keyword analysis of these 112 publications [Fig. 4] links the concept "metaverse" to "Learning" and "Education", as well as to "3D", "Digital-Virtual", "Reality", "Augmented", "Worlds", "Avatar", "Computing", "Systems" or "OpenSim".

This list of concepts shows the need to investigate the relationship between metaverse and education, as pointed out by [73] and, specifically, how it is developing in Higher Education. In this systematic literature review, of the 112 articles reviewed, 30.35% (34 articles) are related to Higher Education.

The evolution of the studies up to 2020 is more or less constant, but it is not until 2021 that we detect a greater increase in indexed publications that address research on the metaverse and, specifically, on the metaverse in Higher Education. In this sense, two phenomena can be associated with this fact. On the one hand, the impact of the COVID-19 pandemic (2019), which has led to an acceleration of digitization processes and the exploration of new digital environments, such as the metaverse [4]. And, on the other hand, the commitment of large corporations, such as Facebook, which has become Meta, in this digital environment since 2021.

From the qualitative content analysis, it can be observed that the metaverse can be considered a virtual learning environment [16], [30]. A complex environment that poses significant challenges for educators and learners and in which the experience is fully immersive, interactive and personalized. In the articles that address the metaverse in Higher Education, two types of analysis are found: theoretical studies and practical experiences in the metaverse, a result like the findings of Tlili, *et al*. [73]. In the case of Higher Education, however, experiments of an educational nature are identified, such as simulation for aircraft maintenance, the practice of teaching second languages [97], [98] or the representation of professional environments, for instance.

The metaverse is a classical framework for the analysis of educational technology, such as the TPACK framework [56], [79], identifying the specific content (discipline), technological and pedagogical elements of the metaverse.

In terms of technology, the educational metaverse is described as a highly digitized and virtualized environment, a virtual world [34] that enables the creation of new places, including educational and learning places. For Kye *et al*. [39] these places can be classified into four categories: augmented reality, lifelogging, mirror world, and virtual reality, all with potential for education [73], [86].

Platforms such as Second Life or Open Sim have served as a space for experimentation in learning and some studies point to the emergence of new environments that can be used in education, such as Gather, Zepeto or Roblox, with greater technological capacity.

While technology is one of the great challenges for the educational metaverse, however, it is important not to lose sight of the pedagogical aspects. How do we teach and learn in the metaverse environment? Cárdenas [11], Pérez-Romero and Moleón-Vilana [65] state that meaningful learning is achieved by what the learner does and not by what the software does.

According to this statement, the design of learning experiences in Higher Education in the metaverse should put the learner at the centre and promote self-directed, autonomous and active learning, based on exploration through the immersive space.

Furthermore, it is important to take advantage of the communicative potential and the interaction and participation options of the environment, based on the networked learning culture, as well as practical learning, based on learning by doing [44], [46], [47]. In this way, the application of practical methodologies is required, such as Problem Based Learning (PBL), with the setting of a clear challenge, as well as Gamified experiences that motivate students and activities that allow for creative development both individually and collectively [83].

In this way, the immersion sensation offered by the platform creates and develops student motivation when learning new contents. Furthermore, it offers the possibility of creating different kinds of activities such as role-plays, educational games, collaboration tools with avatars as characters, and augmented reality tasks [1]. Immersive technology generates an era of immersion in which subjects carry out immersive activities that imply certain forms of behavior and learning. In this way, the importance for immersive learning of the perceptual, sensory, active and pleasurable aspects that precede and complement the cognitive aspects, may be used as a basis for implementing active pedagogical and didactic strategies in the metaverse [72].

The immersive collaboration in the metaverse is another way to strengthen the educational potential of this type of immersion. This collaborative activity is basic to its conformation and operation in metaverse

The immersive potential and autonomy of learners in the metaverse makes it a mirror world, an augmented reality, which allows both representing situations of the "real" (physical) world and even enriching them with virtual elements. For instance, second language classroom teaching has proven to pose a challenge address the specific needs of each learner. The development of the Metaverse and virtual reality technology in recent years could provide a good way to break through this bottleneck [99], as practicing the learning of a second language with anyone in the World in the metaverse makes it possible to

break down geographical walls and carry out international experiences, which are so important for university students.

Another interesting use of the metaverse in Higher Education is to put into practice work environments in which university students can apply their theoretical knowledge in a virtual professional context. Not forgetting also concrete laboratory experiences that can facilitate their development, for example, with the use of dangerous substances; simulation experiences that require a lot of investment in the physical world; or artistic creation in the virtual world.

Finally, it is important, however, not to lose sight of the limitations of the metaverse, such as the high technological dependence (infrastructures, etc.) [31], which can lead to a technological gap, as well as the lack of specific data protection regulations.

V. CONCLUSION

Although it may seem that the metaverse in education is a recent area of research, there has been registered research for more than fifteen years; this systematic bibliographic review aimed to summarize these efforts and build a frame of reference of interest for current educators and researchers, as well as the social value provided in a topic that is in constant development with new technologies.

It has been shown how interest in the subject was growing steadily until the year 2021, in which a considerable increase has been detected with respect to previous years, which responds to the development of the technologies themselves and the value that researchers in general seek to contribute to novel areas.

In this line, it is therefore relevant to call for further research on the metaverse in the field of education (and Higher Education) from 2022 onwards, since an even greater increase in scientific production in this field is expected according to data from the first half of the year.

According to the literature analyzed, the metaverse is an interesting learning space for the development of educational practices in Higher Education in multiple areas of knowledge (Sciences, Health Sciences, Social Sciences, Arts and Humanities, etc.), where experiences have been mostly positive.

Although these practices can be of a theoretical-practical nature, the immersive potential of the metaverse makes it ideal for putting knowledge into practice. In this sense, the student is the true protagonist of the experience, is the center, and assumes a totally active role.

The student creates, looks for solutions, makes his own decisions and acquires, in some way, the necessary competences for his professional, social and labor development, central axes of university education. Just as professors seek to take advantage of the general ecosystem to achieve competencies and learning in a more updated way.

Higher education, in a constant process of evolution, needs to count on these platforms of the digital environment to take advantage of the social impact achieved by virtual spaces where one learns while playing and starring, strengthening the knowledge of students and preparing them at the same time for the management of the technologies in which we already live immersed.

In addition, it has been shown that the Metaverse can be studied from the perspective of a "virtual learning space" in which educational elements are identified from a technological, pedagogical, and content point of view.

VI. LIMITATIONS AND FUTURE WORK

The current work is not without limitations. Epistemic and methodological biases present in bibliographic research are recurrent and, in this case, being a topic in constant change and development, novel at the technological level, it can be recognized that the contributions of the present review are susceptible to expansion at any time, since the social and scientific interest in research on metaverse applications is growing. Still, even if the corpus is relatively reduced, it is still large and diverse; for the current paper purposes, delving deeper into each individual work was out of the scope of the analysis of opportunities and challenges. Despite this, future research should enrich the review and bring additional value by further exploring the specifics of each topic or category, especially as soon as enough works become available in each of them.

As future lines of research, we identify some gaps and propose the following lines: it is necessary to investigate the degree of autonomy of the students and the specific role that the teacher should assume in this environment and the attention to the differences and individual learning styles of the students.

A possible line of research to further contribute and reinforce the metaverse phenomenon as a learning tool in the university environment would be through a qualitative methodology in which professionals who are currently working in the metaverse, explain, in more depth, the advantages of teaching in this "classroom without walls" for the student. It would be a way to contrast what has been published so far about the metaverse with the professional reality, to specify the real scope that this tool can have for higher education.

In addition, it is necessary to pay attention to ethical aspects and to take care of the privacy of these spaces, as well as identity management. In education, it also poses new challenges related to online assessment (e.g., how to assess students in these spaces). Educators are just beginning to realize the potential of the metaverse, and research is catching up.

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