FROM EXTENDED REALITY TO THE METAVERSE: A CRITICAL REFLECTION ON CONTRIBUTIONS TO EDUCATION

De la realidad extendida al metaverso: una reflexión crítica sobre las aportaciones a la educación

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ABSTRACT

Extended reality, a concept that encompasses virtual reality, augmented reality and mixed reality, has seen remarkable progress in recent years and has had a great impact on the understanding of education. Research on extended reality has provided benefits in improving teaching and learning, based on two key concepts: the degree of immersion and the sense of presence. However, these contributions need to be reviewed using a grounded critical methodology to avoid falling into a technophilia without scientific evidence. This article aims to establish and evaluate the contributions extended reality makes to education and the educational challenges it poses in light of the development of the metaverse. For this purpose, firstly, each type of

reality is defined and its applications in the field of education are evaluated from a critical point of view. Secondly, a critical argument is posed about the advantages and disadvantages of these technologies in educational practice. Thirdly, the challenges posed by the metaverse in education are described. This analysis shows how extended reality has contributed to the development of innovation and improvements in the teaching and learning process, although a lack of training for teachers who design learning experiences based on extended reality and a lack of interdisciplinary collaboration between the fields of technology and pedagogy are apparent. These results influence the development of the metaverse, which is another step in the evolution of extended reality that will have a great impact in the field of education. Our findings suggest there is a need to design an ethical code, develop a culture and protect the identity of users.

Keywords: extended reality; metaverse; virtual reality; augmented reality; mixed reality; education theory; ICT; learning.

RESUMEN

La realidad extendida, un concepto que abarca la realidad virtual, la realidad aumentada y la realidad mixta, ha experimentado un notable progreso en los últimos años y ha tenido un gran impacto en la comprensión de la educación. La investigación sobre la realidad extendida ha aportado beneficios en la mejora de la enseñanza y el aprendizaje, a partir de dos conceptos clave: el grado de inmersión y la sensación de presencia. Sin embargo, estas aportaciones necesitan una revisión desde una metodología crítica fundamentada para evitar caer en la tecnofilia sin evidencias científicas. El objetivo de este artículo es conocer y evaluar las aportaciones de la realidad extendida a la educación y los retos que plantea ante el desarrollo del metaverso. Para ello, en primer lugar, se conceptualiza cada tipo de realidad y se evalúan sus aplicaciones en el ámbito de la educación desde un punto de vista crítico. En segundo lugar, se realiza una argumentación fundamentada sobre las ventajas e inconvenientes de estas tecnologías en la práctica educativa. En tercer lugar, se describen los desafíos que plantea el metaverso en la educación. Este análisis muestra como la realidad extendida ha contribuido al desarrollo de la innovación y la mejora del proceso de enseñanza y aprendizaje, aunque se evidencia la falta de formación del profesorado para diseñar experiencias de aprendizaje basadas en la realidad extendida y una carencia de colaboración interdisciplinar entre los ámbitos de la tecnología y la pedagogía. Estos resultados influyen en el desarrollo del metaverso, un paso más en la evolución de la realidad extendida, que tendrá un gran impacto en el ámbito de la educación, lo cual sugiere la necesidad de diseñar un código ético, desarrollar una cultura y proteger la identidad de los usuarios.

Palabras clave: realidad extendida; metaverso; realidad virtual; realidad aumentada; realidad mixta; teoría de la educación; TIC; aprendizaje.

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1. INTRODUCTION

The field of education is seeing how advances in the field of ICT (Information and Communication Technology) are providing new learning tools, allowing students to increase their knowledge beyond temporal and geographic barriers (Cabero, 2013; Cabero *et al*., 2015). Research has shown that the incorporation of ICT into educational practices has had an impact through small ad hoc educational innovations in teachers' methodology, depending on their training and attitudes towards teaching and learning (Area, 2010; Fernández Cruz *et al*., 2018). Emerging technologies are transforming traditional modes of teaching, which are becoming more closely linked to online scenarios (Adell, 1997; Area, 2020). Despite advances in infrastructure, electronic resources and teachers' training and digital competence, ICT has so far only resulted in a superficial change to teaching and learning practices (Area & Adell, 2021).

Over the last decade, online learning has extended to the field of formal education and so research has centred on discovering the possibilities of emerging technologies in virtual settings (Boulton *et al*., 2018; Muñoz-Cristóbal *et al*., 2017). Schroeder (1996, p. 25) defines a virtual environment as "a computer-generated display that allows users to have a sense of being present in an environment other than the one they are actually in, and to interact with that environment". Mobile learning – a focus centred on the learning of knowledge through the use of mobile telephones (Yuen & Yuen, 2008) – stands out among the most widely used trends in virtual environments. This focus favours the development of four types of learning: individualised learning, which allows students to learn at their own pace; situated learning, which involves the use of mobile devices to learn in a real context; collaborative learning, to interact and communicate easily with other students; and informal learning, which happens when students learn outside class at their own pace (Cheon *et al*., 2012). Use of mobile telephones for educational purposes has increased in prominence in recent years (Briz-Ponce *et al*., 2017). Academic literature has centred on mobile learning's impact on students' academic performance (Crompton & Burke, 2018).

The Covid-19 pandemic has highlighted the role of emerging technologies in education. The technologies used most widely with mobile phones are virtual reality (VR), considered to be the learning tool of the twenty-first century (Rogers, 2019), augmented reality (AR) (Arici *et al*., 2019) and mixed reality (MR) (Zhan *et al*., 2020), which together comprise extended reality (XR) (Çöltekin *et al*., 2020a). This concept refers to the combination of virtual and real settings, and how users interact with them (Dall'Acqua & Gironacci, 2019). Advances in extended reality enable the validation of instruments that measure the degree of the sensation of presence that virtual settings provide, opening up new possibilities in education (Gandolfi *et al*., 2021).

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From a theoretical perspective, it is necessary to establish what contributions are offered by extended reality, which can be beneficial by contributing to the circulation of information, or be something damaging that might replace teachers (Meirieu, 2022). Similarly, it is necessary to reflect critically on the contributions extended reality offers to education given the development of the metaverse, which is a challenge the theory of education must confront.

The aim of this article is to establish and evaluate the contributions to education of extended reality (virtual reality, augmented reality and mixed reality) and the educational challenges it poses in view of the development of the metaverse. Starting from a grounded critical methodology, it is first necessary to establish the conceptual basis of each technology and its possibilities in the field of education from a critical perspective, avoiding technophilia or excess enthusiasm without scientific evidence for the possibilities of the new technologies. This article then reflects on the advantages and disadvantages of these technologies in educational practice. Thirdly, it describes the challenges of the metaverse in the education of the future, which open up new lines of research.

2. METHODOLOGY

This work is based around a grounded critical methodology, which starts from a critical social paradigm, based on critical analysis of reality to transform educational practices (Bisquerra, 2009). This methodology makes it possible to reflect on the applications and pros and cons of each type of reality in order to provide knowledge for educational researchers and professionals and apply them in the field of education (McMillan & Schumacher, 2008). A content analysis of the bibliographical references was carried out using the ATLAS.ti program. This enabled the identification of four categories: the concept of each type of reality, its application in the field of education, its advantages and its disadvantages.

3. RESULTS

3.1. *Concept and contributions to education of virtual reality*

Virtual reality (VR) is a digitally constructed simulated environment, which features visual and sound effects that make users believe that they are in an environment that really exists. It can be used in the field of education, immersing students in a space created to make them feel different emotions, for example walking around the cities of ancient Egypt (Gómez-García *et al.*, 2020). It comprises two key concepts: immersion and presence. The former describes the experience of using technology that introduces us into an imaginary realm and works by interchanging sensory information about reality with other digitally created information, such as images and sounds (Ott & Freina, 2015). The latter

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refs to the subjective reaction users experience when immersed in a virtual environment, so that the brain behaves in a similar way to when it is in the real world (Slater, 2003).

Academic literature has highlighted the use of virtual reality in education and its possibilities in the teaching–learning process. Virtual reality laboratories for teaching STEM (Science, Technology, Engineering and Mathematics) content make it possible to carry out simulations of experiments using objects created in 3D (Potkonjak *et al.*, 2016). Few studies have designed virtual reality applications, based on a specific theory of learning and researched how it can be integrated into the curriculum (Radianti *et al.*, 2020).

Research has found that virtual reality situations can produce mild feelings of unsafety up to other more serious cases of cybersickness (Jensen & Konradsen, 2017), underlining the importance of designing situations that minimise physical discomfort. The study by Krokos *et al.* (2019) found that students retain more information and apply what they have learnt better after participating in educational experiences using virtual reality.

3.1.1. Advantages and disadvantages of virtual reality

The advantages of VR derive from its capacity to make users feel present in a situation. Students feel a greater sensation of presence when immersed in a virtual reality situation with an HMD (Head-Mounted Display), a display unit that is similar to a helmet, but they learn less in comparison to other low-immersion situations using a computer (Makransky *et al.*, 2017). The drawbacks of VR are the technical difficulties of using it and the high cost of the equipment needed to carry out experiences with a high level of immersion (Duncan *et al.*, 2012), which have hampered its implementation in educational practice. Consequently, the advantages of virtual reality with regards to students' sensation of emotions have not been consolidated in education owing to the sophistication and investment required for the devices needed to implement it in the classroom.

3.2. *Concept and contributions of augmented reality in education*

The researcher and scientist Thomas P. Caudell coined the term "augmented reality" (AR) in 1992 to define a technology that makes it possible to augment the field of vision through head-up displays (Caudell & Mizell, 1992; Lee, 2012). Augmented reality is a technology that enables users to see a reality complemented by superimposing virtual objects on the real world (Azuma, 1997). It is a setting that includes elements of two worlds (real and virtual), maintains interaction in real time and can be shown in three dimensions (Gómez & Palomo, 2016, p. 141). Since 2010, research into the application of AR in education has increased

noticeably owing to the integration of AR systems in smartphones and tablets, which stand out among emerging technologies (Garzón *et al*., 2019).

The use of AR in education allows teachers and students to take notes in the real world, simultaneously interact with real and virtual objects and do practical work with virtual objects in a real situation, for example dissecting animals, without risk (Gómez-García & Palomo, 2016). Accordingly, one of the fields where AR has the greatest impact is the STEM, where AR-based exploration tools are used, alongside research and simulation activities (Ibáñez & Delgado-Kloos, 2018). In mathematics, use of AR in educational practice has a significant effect on students' understanding of concepts (Boaler *et al*., 2016), problem-solving ability (Sollervall, 2012) and academic performance (Demitriadou *et al*., 2020). One of the most common types of AR in the educational sphere is GPS geolocation, a technology that makes it possible to find one's geographical position anywhere on earth and access maps through geo-positioning and real-time information (Brazuelo, 2015). Geolocation and augmented reality contribute to carrying out activities for exploring the environment and of geographical concepts independently (Arango-López *et al*., 2019; Fombona & Vázquez-Cano, 2017).
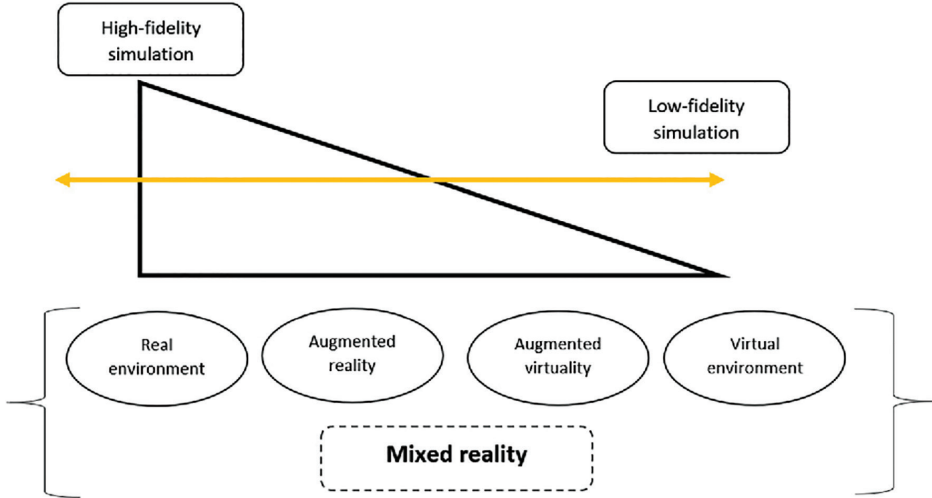
3.2.1. Advantages and disadvantages of augmented reality

The advantages of AR in education lie in its capacity to increase student participation in activities through immersive technologies and improve the learning experience (Suh & Prophet, 2018). Use of AR in educational practice has a moderate effect on students' academic results (Garzón & Acevedo, 2019). AR's drawbacks relate to its complexity, which underlines the need for specific training for teachers to create content that improves the teaching–learning process (Pellas *et al*., 2018). AR poses challenges for improving the teaching–learning process in educational practice: teachers' lack of training and experience, the need for more class time to perfect its use and its unsuitability in classes with high ratios (Ackayir & Ackayir, 2017). AR involves another step towards combining VR and the physical world, which contributes to student motivation even if there are training shortfalls in university curriculums relating to its implementation in educational practice.

3.3. *Concept and contributions to education of mixed reality*

Milgram and Kishino (1994), two pioneering technology researchers, explained the possibilities of MR for improving learning "anywhere between the extrema of the virtuality continuum" (p. 1322), in which virtual contexts extend from real settings to virtual ones through technology that can "augment" the user's experience. Accordingly, they coined the term "reality–virtuality continuum" (see Figure 1), to describe the development of MR.

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FIGURE 1
EVOLUTION OF MIXED REALITY

Source: Pellas *et al.* (2019)

MR is a combination of AR and VR, and offers the possibility of interacting physically with virtual objects in the real world (Yusoff *et al.*, 2011). It can be used to develop "augmented" settings within real-world settings in which users can aggregate or integrate virtual information (Tamura *et al.*, 2001). In MR scenarios, data are processed through a variety of different input devices, such as smart glasses, tablets, sensors or personal computers (PC), which are connected to output devices such as projectors, interactive walls or computer monitors that show the results of the processing. The input and output devices must all be integrated into a physical environment that improves the user's feeling of "presence" (Ponto *et al.*, 2016). The principal difference between AR and MR is that the former allows virtual objects to be superimposed in the real world, while the latter is a medium that incorporates a set of virtual and real elements through a continuum of reality (Lindgren & Johnson-Glenberg, 2013). Research has shown that use of MR is effective in the teaching–learning process (Ke *et al.*, 2016; Tang *et al.*, 2020).

The principal challenges that VR, AR and MR pose are personalisation of learning and educational intelligence. Personalisation of learning involves creating and implementing learning experiences based on the educational needs and characteristics of the students (prior knowledge of a topic, interests and learning styles).

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Educational intelligence is the application of new technologies and smart methods that improve students' learning (Kurilovas, 2016).

The application of MR in the educational sphere is a topic that has been considered in depth in much research (Johnson-Glenberg *et al*., 2014; Tscholl & Lindgren, 2016). The application of mixed reality to education has given rise to a focus called MRLE (Mixed Reality Learning Environment) (Chang *et al*., 2010). One of the applications of MRLE that has had the biggest impact in learning is the use of mobile phones in the sciences, through the design of mixed-reality laboratories that allow users to focus on laboratory tests, augment graphics, modify them and perform experiments (Frank & Kapila, 2017). This has also been used in the field of astronomy for teaching about outer space (Lindgren *et al*., 2016).

Student motivation is an important factor in academic performance (Trowler, 2010). Use of both VR and MR has more impact on student motivation than traditional methods, and so have an influence on improving academic performance (Allcoat *et al*., 2021; Leonard & Fitzgerald, 2018). Use of MR in educational practice improves students' academic performance, in particular those who have low spatial abilities (Weng *et al*., 2020).

3.3.1. Advantages and disadvantages of mixed reality

The advantages of MR relate to its multiple applications from a methodological perspective, as it combines the possibilities of VR and AR into one focus, leading to the design and development of learning experiences that provide relevance, interest and significance to students' learning. One of the focuses where MR stands out is the *serious game*. This consists of a digital game intended to entertain while achieving at least one educational objective, thus promoting problem solving (Dörner *et al*., 2016). Accordingly, MR-based serious games contribute to students resolving a meaningful problem collaboratively, making use of the possibilities that both realities offer (Lee *et al*., 2016). The drawbacks of using MR in education relate to the lack of interdisciplinary collaboration between technological research into the devices used in MR (for example, smart glasses) and pedagogical research regarding its application in educational practice. Effective MR-based experiences can only be created through interdisciplinary collaboration, consolidating and accepting advances from different disciplines such as technology and education, given that separate advance of the disciplines entails the risk of making one-way suppositions about the use of technologies (Çoltekin *et al*., 2020b). In this way, advances in knowledge about these new technologies encourages interdisciplinary focuses with great potential, enabling all sorts of methodologies and applications (Prendes & Cerdán, 2021).

Our literature review has shown a lack of studies on the use of AR and VR for educational purposes owing to three factors: 1. Access to these technologies through smartphones, use of which has not yet become consolidated in the

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teaching–learning process; 2. The lack of content relating to the use of these technologies in educational institutions; and 3. The digital divide within countries and schools (Maas & Hughes, 2020). MR experiences in the metaverse require verbal interaction with virtual objects and receiving feedback, and so voice inter-action is the principal challenge in moving from MR to the development of the metaverse in education (Siyaev & Jo, 2021). To do so, it is necessary to perfect development of the glasses used in MR, which function with static and predefined voice commands (Eschen *et al.*, 2018), and include other flexible ones that adapt to feedback from users.

3.4. *Concept and contributions of the metaverse to education*

In 2021, Mark Zuckerberg announced that the metaverse would arrive within five to ten years, describing it as an alternative digital reality in which people work, play and socialise (Gonzalo, 2021). Since then, opinion pieces on the possible social consequences of the metaverse and its impact on e-learning have proliferated, under-lining the importance and currency of the matter. To establish what challenges the metaverse poses for future digital scenarios, it is best to start from its concept and works published in academic journals that have considered this new reality. The concepts that relate to the metaverse are "mirror world" or "spacial internet", and so it can be understood as "a virtually enhanced physical reality" (Ribeiro, 2021).

The metaverse is an acronym formed by the prefix "meta" (of a higher kind) and a contraction of the term universe – "verse" – referring to an immersive, interactive and collaborative virtual 3D world. It represents a new dimension in the internet that will have a significant impact on education in the future (Rodríguez, 2021). The US novelist Neal Stephenson (1992) was the first person to use this term in his novel *Snow Crash* to refer to a new version of the internet. It makes it possible for different members of a group to work together in a virtual space through avatars that interact face to face and create three-dimensional objects that represent ideas, values or feelings (Davis *et al.*, 2009).

The metaverse combines a series of characteristics that go beyond extended reality (Ball, 2020; Martín-Ramallal & Merchán-Murillo, 2019):

- It is persistent. It does not restart or pause, but instead continues indefinitely.
- It favours proactivity by users, who take control, make decisions and anticipate possible events.
- It is synchronous and exists in real time.
- It does not place limits on simultaneous users in an activity.
- It offers an experience that encompasses the digital and the real worlds, the relationship between private and public networks.
- It offers interoperability of data and digital elements, for example, a virtual object from a video game can be given to a friend via Facebook.

One educational possibility of the metaverse is the creation of museums that house exhibitions on special topics and provide experiential content to visitors (Choi & Kim, 2017). Others relate to the design of learning experiences based in the metaverse. These require the creation of an avatar, an alter ego of the user that can interact with other avatars in a virtual world (Bailenson & Yee, 2005). The Horizon Report 2021 highlights the use of avatars for practising languages in a virtual environment. The avatar is connected to a chatbot, which provides answers to the students' doubts (Pelletier *et al.*, 2021). One pioneering study evaluated the social perception of people based on creating two avatars, one with the same facial appearance as the users and another with the same facial expressions and gestures. The results show that participants did not identify with the appearance of their avatar, while they did recognise themselves in the avatars that made the same facial expressions and gestures as them. Therefore, this behavioural realism plays an important role in the design of avatars to implement the metaverse (Park *et al.*, 2021).

3.4.1. Challenges of the metaverse in education

The principal challenge lies in moving from a sophisticated but independent virtual reality environment to an integrated network of 3D virtual worlds or metaverse. This challenge underlines the need to progress in understanding of four areas that have an impact on education (Dionisio *et al.*, 2013): 1. Realism (making users feel that they are immersed in an alternative dimension); 2. Ubiquity (establishing access to the system through digital devices and maintaining users' virtual identities within the system); 3. Interoperability (allowing the creation and movement of 3D objects outside the system); and 4. Scalability (enabling efficient use of the system with massive numbers of users connected at once). From a practical viewpoint, the first experiments that have approached the metaverse have centred on reading and listening comprehension and written expression in languages (Garrido-Íñigo & Rodríguez-Moreno, 2013).

The metaverse offers many educational possibilities relating to the acquisition of cultural knowledge (Zheng, 2020). Accordingly, one key concept in the development of the metaverse is culture, which refers to the background and experiences of the people who form part of this dimension (Han, 2015) and encompasses two related concepts: who we are and how we live (Wang, 2001). Castells (2005, p. 405) argues for the necessity of a culture in the knowledge society based on establishing certain norms. He observes that this culture forms part of a system of real virtuality in which reality itself (the existence of people) is submerged in a scenario of virtual images, where appearances are not only on the screen through which the experience is communicated, but also become the experience. In this sense, it is fundamental to construct a culture or set of norms and values as a basis for communicating, working and being in the metaverse, an

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alternative reality in which the boundaries between the physical and the virtual are still vague and must be delineated with precision to protect users' identities. Accordingly, Smithson (2022) suggests the need for an ethical code to develop the culture of the metaverse, based on five aspects:

1. Transparency of knowledge and opinions between consumers and creators of products based in the metaverse will help improve its functioning.
2. A scale of values that favours coexistence and relations between users.
3. The principle of inclusion is fundamental. The metaverse must be accessible and easy to use for everyone.
4. The avatars (or alter egos) are real people, and so harassment or fraudulent behaviour will be punished with temporary suspension of users from this space.
5. Ethics are the cornerstone that results in the design of programs and learning experiences that guarantee the confidentiality of the consumers.

4. Conclusions

The Covid-19 pandemic resulted in teaching moving onto digital platforms, marking a turning point in the implementation of emerging technologies in the education of the future, where extended reality and the metaverse stand out for their relevance, interest and impact on the teaching–learning process. Therefore, the fundamental aim of this study was to establish and evaluate the scientific contributions of extended reality (virtual reality, augmented reality and mixed reality) to the field of education, as well as the challenges the metaverse poses in the education of the future.

Regarding the concept of the three types of realities that make up extended reality, VR combines visual and sound effects to make users believe that they are in an environment that exists in reality. The fundamental objective of this reality is to address immersion in a virtual setting without foregoing presence or the subjective reaction of the users. These two concepts – immersion and presence – have guided later studies on augmented reality, which offers the possibility of physical interaction with virtual objects in the real world. AR has been bolstered by smartphones and tablets, which have facilitated its development in education. Mixed reality has emerged in an attempt to increase the degree of immersion and presence, incorporating virtual and real elements through a continuum of reality and providing an important precursor to the development of the metaverse, a 3D virtual world, that requires the creation of an avatar to interact with other avatars in a virtual world.

Regarding its application in the educational sphere, VR has centred on the design of laboratories in STEM subjects for carrying out simulations of experiments without any risk. Use of AR has spread to the area of mathematics, in order to explain concepts, and geography, to explore geographical settings through

geolocation. The implementation of mixed reality has involved refining laboratory tests in the sciences through modifying and augmenting graphics, as well as teaching concepts about outer space in the field of astronomy. It has also involved a notable advance in the development of new methodological proposals, such as serious games.

With regards to the advantages and disadvantages of extended reality, virtual reality offers a greater sensation of immersion and presence than traditional methodologies, but the cost of the equipment needed to implement quality experiences in educational centres is high. Augmented reality favours students' motivation towards learning, even though teachers do not have the necessary training to implement it in educational practice. Mixed reality, for its part, promotes the development of diverse methodological strategies, even though advances in the fields of technology and pedagogy have followed parallel courses without interdisciplinary collaboration to progress in knowledge about the possibilities of MR in education.

There are four major challenges to develop extended reality in the educational sphere (Fernández, 2021; López-Rupérez, 2020; NEPT, 2017):

- The major investment centres need to make to implement VR and AR to enable the creation of new learning experiences in digital laboratories.

- Personalised education, which takes into account the starting point of each student so that the pace of learning and the focus of the teaching are organised in accordance with the students' individual needs.

- Integration of active methodologies and emerging technologies, which entails the development of methodologies such as flipped classroom in which students prepare the lesson plan before a class and spend class time delivering this content.

- The search for meaningful learning, that does not regard emerging technologies as an end in themselves but also as a tool in the service of teachers and students to improve the teaching–learning process.

These challenges affect the development of the metaverse, which is destined to be revolutionary in the fields of new technologies, communication and education. In this new reality, it is necessary to design an avatar, which represents the user and interacts with other avatars to communicate, work and collaborate, thus opening up many possibilities in e-learning and transcending temporal and geographical barriers. Three aspects will be important in future research:

1. Development of the metaverse could blur the boundaries between the real and virtual worlds. This suggests there is a need to design and develop an ethical code to acts as a guide to using the metaverse with greater safely. It is not a matter of this "alternative" reality supplanting reality itself. Instead it is perceived as a new continuum of the virtually improved reality, which opens new possibilities in the teaching–learning process.

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2. This ethical code favours the development of a culture, that involves designing and implementing norms that acquire a meaning in the metaverse and become consolidated with experience. Two fundamental aspects of this ethical code are the principle of inclusivity and values that favour the development of relationships between users.

3. Protecting users' identities. Creating an avatar involves defining an alter ego, which combines a series of physical and/or personality features that define us as individuals in the metaverse and differentiate us from other avatars. This situation imposes a need to guarantee the confidentiality of personal data.

In conclusion, it can be asserted that the shift from extended reality to the metaverse in e-learning involves a different approach, insofar as immersion and presence comprise a means of improving the teaching–learning process, while in the metaverse they represent an end in themselves, in a virtually improved reality. Greater interdisciplinary collaboration between the fields of technology and research in education is needed to ensure that the implementation of the metaverse in e-learning results in improvements to teaching and learning.

References

Adell, J. (1997). Tendencias en educación en la sociedad de las tecnologías de la información. *Edutec. Revista Electrónica de Tecnología Educativa*, (7), a007. https://doi.org/10.21556/edutec.1997.7.570

Akçayır, M., & Akçayır, G. (2017). Advantages and challenges associated with augmented reality for education: A systematic review of the literature. *Educational Research Review, 20*(1), 1-11. https://doi.org/10.1016/j.edurev.2016.11.002

Allcoat, D., Hatchard, T., Azmat, F., Stansfield, K., Watson, D., & von Mühlenen, A. (2021). Education in the digital age: Learning experience in Virtual and Mixed Realities. *Journal of Educational Computing Research, 59*(5), 795-816. https://doi.org/10.1177/0735633120985120

Arango-López, J., Cerón, C. C., Collazos, C.A., Gutiérrez, F. L., & Moreira, F. (2019). Creando: Tool for creating pervasive games to increase the learning motivation in higher education students. *Telematics and Informatics,* (38), 62-73. https://doi.org/10.1016/j.tele.2018.08.005

Area, M. (2010). El proceso de integración y uso pedagógico de las TIC en los centros educativos. Un estudio de casos. *Revista de Educación*, (352), 77-97.

Area, M. (2020). *Escuela Digital. Los materiales didácticos en la Red*. Graó.

Area, M., & Adell, J. (2021). Tecnologías digitales y cambio educativo. Una aproximación crítica. *REICE. Revista Iberoamericana sobre Calidad, Eficacia y Cambio en Educación, 19*(4), 83-96. https://doi.org/10.15366/reice2021.19.4.005

Arici, F., Yildirim, P., Caliklar, S., & Yilmaz, R. M. (2019). Research trends in the use of augmented reality in science education: Content and bibliometric mapping analysis. *Computers & Education, 142*(103647), 1-44. https://doi.org/10.1016/j.compedu.2019.103647

Azuma, R. (1997). A survey of augmented reality. *Presence: Teleoperators and Virtual Environments*, *6*(4), 355-385. https://doi.org/10.1162/pres.1997.6.4.355

Bailenson, J. N., & Yee, N. (2005). Digital chameleons: Automatic assimilation of nonverbal gestures in immersive virtual environments. *Psychological Science, 16*(10), 814-819. https://doi.org/10.1111/j.1467-9280.2005.01619.x

Ball, M. (14 de enero de 2020). *The Metaverse: what it is, where to find it, and who will build it.* https://bit.ly/34U1SW5

Bisquerra, R. (2009). *Metodología de la investigación educativa*. La Muralla.

Boaler, J., Chen, L., Williams, C., & Cordero, M. (2016). Seeing as understanding: The importance of visual mathematics for our brain and learning. *Journal of Applied & Computational Mathematics, 5*(5), 1-6. https://doi.org/10.4172/2168-9679.1000325

Boulton, C. A., Kent, C., & Williams, H. (2018). Virtual learning environment engagement and learning outcomes at a "bricks-and-mortar" university. *Computers & Education,* (126), 129-142. https://doi.org/10.1016/j.compedu.2018.06.031

Brazuelo, F. (2015). Recursos móviles y realidad aumentada. En M. L. Cacheiro, C. Sánchez & J. M. González (Coords.), *Recursos tecnológicos en contextos educativos* (pp. 399-432). UNED.

Briz-Ponce, L., Pereira, A., Carvalho, L., Juanes-Méndez, J. A., & García-Peñalvo, F. J. (2017). Learning with mobile technologies-Students´ behaviour. *Computers in Human Behavior, 72*, 612-620. https://doi.org/10.1016/j.chb.2016.05.027

Cabero, J. (2013). La formación virtual en el nuevo entramado 2.0: el e-learning 2.0. En J. I. Aguaded & J. Cabero (Coords.), *Tecnologías y medios para la educación en la e-sociedad* (pp. 23-52). Alianza.

Cabero, J., Barroso, J., & Llorente M. C. (2015). Tecnología educativa: historia, concepto y bases conceptuales. En J. Cabero & J. Barroso (Coords.), *Nuevos retos en tecnología educativa* (pp. 19-39). Síntesis.

Castells, M. (2005). *La era de la información: economía, sociedad y cultura. Volumen 1.* Siglo XXI editores.

Caudell, T. P., & Mizell, D. W. (1992). Augmented reality: an application of heads-up display technology to manual manufacturing processes. *Proceedings of the Twenty-Fifth Hawaii International Conference on System Sciences*, *2*, 659-669. https://doi.org/10.1109/HICSS.1992.183317

Chang, C. W., Lee, J. H., Wang, C. Y., & Chen, G. D. (2010). Improving the authentic learning experience by integrating robots into the mixed-reality environment. *Computers & Education, 55*(4), 1572-1578. https://doi.org/10.1016/j.compedu.2010.06.023

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Cheon, J., Lee, S., Crooks, S. M., & Song, J. (2012). An investigation of mobile learning readiness in higher education based on theory of planned behavior. *Computers & Education, 59*(3), 1054-1064. https://doi.org/10.1016/j.compedu.2012.04.015

Choi, H., & Kim, S. (2017). A content service deployment plan for metaverse museum exhibitions-Centering on the combination of beacons and HMDs. *International Journal of Information Management, 37*(1), 1519-1527. https://doi.org/10.1016/j.ijinfomgt.2016.04.017

Çöltekin, A., Griffin, A. L., Slingsby, A., Robinson, A. C., Christophe, S., Rautenbach, V., Chen, M., Pettit, C., & Klippel, A. (2020a). Geospatial information visualization and extended reality displays. En *Manual of Digital Earth* (pp. 229-277). Springer.

Çöltekin, A., Lochhead, I., Madden, M., Christophe, S., Devaux, A., Pettit, C., Lock, O., Shukla, S., Herman, L., Stachon, Z., Kubícek, P., Snopkova, D., Bernardes, S., & Hedley, N. (2020b). Extended Reality in spatial sciences: A review of research challenges and future directions. *ISPRS International Journal of Geo-Information, 9*(7), 1-29. https://doi.org/10.3390/ijgi9070439

Crompton, H., & Burke, D. (2018). The use of mobile learning in higher education: A systematic review. *Computers & Education, 123*, 53-64. https://doi.org/10.1016/j.compedu.2018.04.007

Dall´Acqua, L., & Gironacci, I. M. (2019). *Political decision-making and security intelligence: Recent techniques and technological developments*. IGI Global.

Davis, A., Khazanchi, D., Murphy, J., Zigurs, I., & Owens, D. (2009). Avatars, people, and virtual worlds: Foundations for research in metaverses. *Journal of the Association for Information Systems, 10*(2), 90-116. https://doi.org/0.17705/1jais.00183

Demitriadou, E., Stavroulia, K. E., & Lanitis, A. (2020). Comparative evaluation of virtual and augmented reality for teaching mathematics in primary education. *Education and Information Technologies, 25*(1), 381-401. https://doi.org/10.1007/s10639-019-09973-5

Dionisio, J. D., Burns, W. G., & Gilbert, R. (2013). 3D virtual worlds and the metaverse: Current status and future possibilities. *AMC Computing Surveys, 45*(3), 1-38. https://doi.org/10.1145/2480741.2480751

Dörner, R., Göbel, S., Effelsberg, W., & Wiemeyer, J. (2016). *Serious games. Foundations, concepts and practice*. Springer.

Duncan, I., Miller, A., & Jiang, S. (2012). A taxonomy of virtual worlds usage in education. *British Journal of Educational Technology, 43*(6), 949-964. https://doi.org/10.1111/j.1467-8535.2011.01263.x

Eschen, H., Kötter, T., Rodeck, R., Harnisch, M., & Schüppstuhl, T. (2018). Augmented and Virtual Reality for inspection and maintenance processes in the aviation industry. *Procedia Manufacturing, 19*, 156-163. https://doi.org/10.1016/j.promfg.2018.01.022

Fernández, J. A. (20 de noviembre de 2021). Cinco asignaturas que debe aprobar la universidad que viene. *El País*. https://bit.ly/3Kli1En

Fernández Cruz, F. J., Fernández Díaz, M. J., & Rodríguez Mantilla, J. M. (2018). El proceso de integración y uso pedagógico de las TIC en los centros educativos madrileños. *Educación XX1, 21*(2), 395-416. https://doi.org/10.5944/educxx1.17907

Fombona, J., & Vázquez-Cano, E. (2017). Posibilidades de utilización de la Geolocalización y realidad aumentada en el ámbito educativo. *Educación XX1, 20*(2), 319-342. https://doi.org/10.5944/educXX1.19046

Frank, J. A., & Kapila, V. (2017). Mixed-reality learning environments: Integrating mobile interfaces with laboratory test-beds. *Computers & Education, 110*(4), 88-104. https://doi.org/10.1016/j.compedu.2017.02.009

Gandolfi, E., Kosko, K. W., & Ferdig, R. E. (2020). Situating presence within extended reality for teacher training: Validation of the extended Reality Presence Scale (XRPS) in preservice teacher use of immersive 360 video. *British Journal of Educational Technology, 52*(2), 824-841. https://doi.org/10.1111/bjet.13058

Garzón, J., & Acevedo, J. (2019). Meta-analysis of the impact of Augmented Reality on students' learning gains. *Educational Research Review, 27*(1), 244-260. https://doi.org/10.1016/j.edurev.2019.04.001

Garzón, J., Pavón, J., & Baldiris, S. (2019). Systematic review and meta-analysis of augmented reality in educational settings. *Virtual Reality, 23*(1), 447-459. https://doi.org/10.1007/s10055-019-00379-9

Garrido-Íñigo, P., & Rodríguez-Moreno, F. (2013). The reality of virtual worlds: pros and cons of their application to foreign language teaching. *Interactive Learning Environments, 23*(4), 1-18. https://doi.org/10.1080/10494820.2013.788034

Gómez-García, M., & Palomo, R. (2016). Realidad aumentada y recursos móviles. En J. Sánchez, J. Ruiz, & M. Gómez García (Coords.), *Tecnologías de la Comunicación y la Información aplicadas a la educación* (pp. 131-149). Síntesis.

Gómez-García, M., Palomo, R., Guillén, F. D., & Pérez, R. (2020). Aprendizaje con móviles. realidad virtual, aumentada y mixta. En E. Sánchez, E. Colomo & J. Ruiz (Coords.), *Tecnologías de la Información y la Comunicación en Contextos Educativos* (pp. 141-152). Síntesis.

Gonzalo, M. (26 de octubre de 2021). *Metaverso, ¿para cuándo? O cómo reconocerlo cuando llegue*. https://bit.ly/3Gesijl

Han, H. C. (2015). Teaching visual learning through virtual world experiences: Why do we need a virtual world for art education? *Art Education, 68*(6), 22-27. https://doi.org/10.1080/00043125.2015.11519344

Ibáñez, M. B., & Delgado-Kloos, C. (2018). Augmented reality for STEM learning: A systematic review. *Computers & Education, 123*, 109-123. https://doi.org/10.1016/j.compedu.2018.05.002

PABLO JAVIER ORTEGA-RODRÍGUEZ
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Jensen, L., & Konradsen, F. (2017). A review of the use of virtual reality head-mounted displays in education and training. *Education and Information Technologies, 23*(4), 1515-1529. https://doi.org/10.1007/s10639-017-9676-0

Johnson-Glenberg, M. C., Birchfield, D. A., Tolentino, L., & Koziupa, T. (2014). Collaborative embodied learning in mixed reality motion-capture environments: Two science studies. *Journal of Educational Psychology, 106*(1), 86-104. https://doi.org/10.1037/a0034008

Ke, F., Lee, S., & Xu, X. (2016). Teaching training in a mixed-reality integrated learning environment. *Computers in Human Behavior, 62,* 212-220. https://doi.org/10.1016/j.chb.2016.03.094

Krokos, E., Plaisant, C., & Varshney, A. (2019). Virtual memory palaces: immersion aids recall. *Virtual Reality,* (23), 1-15. https://doi.org/10.1007/s10055-018-0346-3

Kurilovas, E. (2016). Evaluation of quality and personalization of VR/AR/MR learning systems. *Behaviour and Information Technology, 35*(11), 998-1007. https://doi.org/10.1080/0144929X.2016.1212929

Lee, K. (2012). Augmented reality in education and training. *TechTrends, 56*(2), 13-21. https://doi.org/10.1007/s11528-012-0559-3

Lee, H., Parsons, D., Kwon, G., Kim, J., Petrova, K., JEong, W., & Ryu, H. (2016). Cooperation begins: Encouraging critical thinking skills through cooperative reciprocity using a mobile learning game. *Computers & Education, 97*, 97-115. https://doi.org/10.1016/j.compedu.2016.03.006

Leonard, S. N., & Fitzgerald, R. N. (2018). Holographic learning: A Mixed Reality trial of Microsoft holoLens in an Australian Secondary School. *Research in Learning Technology, 26*, 1-12. https://doi.org/10.25304/rlt.v26.2160

Lindgren, R., & Johnson-Glenberg, M. (2013). Emboldened by embodiment: Six precepts for research on embodied learning and mixed reality. *Educational Researcher, 42*(8), 445-452. https://doi.org/10.3102/13189X13511661

Lindgren, R., Tscholl, M., Wang, S., & Johnson, E. (2016). Enhancing learning and engagement through embodied interaction within a mixed reality simulation. *Computers & Education, 95*(1), 174-187. https://doi.org/10.1016/j.compedu.2016.1.1

López-Rupérez, F. (2020). *El currículo y la educación en el siglo XXI. La preparación del futuro y el enfoque por competencias*. Narcea.

Maas, M. J., & Hughes, J. M. (2020). Virtual, augmented and mixed reality in K-12 education: a review of the literature. *Technology, Pedagogy and Education, 29*(2), 231-249. https://doi.org/10.1080/1475939X.2020.1737210

Makransky, G., Terkildsen, T. S., & Mayer, R. E. (2017). Adding immersive virtual reality to a science lab simulation causes more presence but less learning. *Learning & Instruction, 60*, 225-236. https://doi.org/10.1016/j.learninstruc.2017.12.007

Martín-Ramallal, P., & Merchán-Murillo, A. (2019). Realidad virtual. Metaversos como herramienta para la teleformación. En P. Casas-Moreno, G. Paramio-Pérez & V. B. Gómez Pablos (Eds.), *Realidades educativas en la esfera digital: Sistemas, modelos y paradigmas de aprendizaje* (pp. 15-38). Egregius Ediciones.

McMillan, J., & Schumacher, S. (2008). *Investigación educativa: una introducción conceptual*. Pearson.

Meirieu, Ph. (2022). El futuro de la Pedagogía. *Teoría de la Educación. Revista Interuniversitaria, 34*(1), 69-81. https://doi.org/10.14201/teri.27128

Milgram, P., & Kishino, A. (1994). Taxonomy of mixed reality visual displays. *IEICE Transactions on Information and Systems, 12*(12), 1321-1329.

Muñoz-Cristóbal, J. A., Gallego-Lema, V., Arribas-Cubero, H. F., Martínez-Monés, A., & Asensio-Pérez, J. I. (2017). Using virtual learning environments in bricolage mode for orchestrating learning situations across physical and virtual spaces. *Computers & Education, 109,* 233-252. https://doi.org/10.1016/j.compedu.2017.03.004

NEPT. (2017). *Reimagining the role of technology in education.* U.S. Department of Education. https://tech.ed.gov.

Ott, M., & Freina, L. (23 de abril de 2015). *A literature review on immersive virtual reality in education: state of the art and perspectives* [Presentación de paper]. Conference: eLearning and Software for Education, Bucarest, Rumanía. https://bit.ly/3DdqeFT

Park, S., Kim, S. P., & Whang, M. (2021). Individual's social perception of virtual avatars embodied with their habitual facial expressions and facial appearance. *Sensors, 21* (5986), 1-18. https://doi.org/10.3390/s21175986

Pellas, N., Fotaris, P., Kazanidis, I., & Wells, D. (2018). Augmenting the learning experience in primary and secondary school education: a systematic review of recent trends in augmented reality game-based learning. *Virtual Reality, 23*(4), 329-346. https://doi.org/10.1007/s10055-018-0347-2

Pellas, N., Kazanidis, I., & Palaigeorgiou, G. (2019). A systematic literature review of mixed reality environments in K-12 education. *Education and Information Technologies, 25*, 2481-2520. https://doi.org/10.1007/s10639-019-10076-4

Pelletier, K., Brown, M., Brooks, C., McCormack, M., Reeves, J., Arbino, N., Bozkurt, A., Crawfors, S., Czerniewicz, L., Gibson, R., Linder, K., Mason, J., & Mondelli, V. (2021). *EDUCAUSE Horizon Report. Teaching and Learning Edition*. Educause.

Ponto, K., Kuester, F., Nideffer, R., & Penny, S. (2006). Virtual bounds: A teleoperated mixed reality. *Virtual Reality, 10*(1), 41-47. https://doi.org/10.1007/s10055-006-0030-x

Potkonjak V., Gardner M., Callaghan V., Mattila P., Guetl C., Petrović V. M., & Jovanović K. (2016). Virtual Laboratories for Education in Science, Technology, and Engineering. *Computers & Education, 95,* 309-327. https://doi.org/10.1016/j.compedu.2016.02.002

Prendes, M. P., & Cerdán , F. (2021). Tecnologías avanzadas para afrontar el reto de la innovación educativa. *RIED. Revista Iberoamericana de Educación a Distancia, 24(*1), 35-53. https://doi.org/10.5944/ried.24.1.28415

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Radianti, J., Majchrzak, T. A., Fromm, J., & Wohlgennant, I. (2020). A systematic review of immersive virtual reality applications for higher education: Design elements, lessons learned, and research agenda. *Computers & Education, 147*, 1-33. https://doi.org/10.1016/j.compedu.2019.103778

Ribeiro, R. (15 de noviembre de 2021). Metaverse and the educational potential: Is it so far away? *Cambridge University Press*. https://bit.ly/34PDBR0

Rodríguez, P. (2021). *Metaverso: hay otros mundos, pero están en éste*. Fundación Telefónica. https://bit.ly/3qEHvVe

Rogers, S. (2019). *Virtual reality: The learning aid of the 21st century*. Forbes

Schroeder, R. (1996). *Possible Worlds: The Social Dynamic of Virtual Reality Technologies*. Westview Press.

Siyaev, A., & Jo, G. S. (2021). Towards aircraft maintenance metaverse using speech interactions with virtual objects in Mixed Reality. *Sensors, 21*(6), 1-21. https://doi.org/10.3390/s21062066

Slater, M. (2003). A note on presence terminology. *Presence Connect, 3*(3), 1-5.

Smithson, A. (5 de enero de 2022). *The Metaverse Manifesto*. https://bit.ly/3tdHfyu

Sollervall, H. (2012). Collaborative mathematical inquiry with augmented reality. *Research & Practice in Technology Enhanced Learning, 7*(3), 153-173.

Stephenson, N. (1992). *Snow Crash*. Bantam Books.

Suh, A., & Prophet, J. (2018). The state of immersive technology research: A literature analysis. *Computers in Human Behavior, 86*, 77-90. https://doi.org/10.1016/j.chb.2018.04.019

Tamura, H., Yamamoto, H., & Katayama, A. (2001). Mixed reality: Future dreams seen at the border between real and virtual worlds. *Computer Graphics and Applications, 21*(6), 64-70. https://doi.org/10.1109/38.963462

Tang, Y. M., Au, K. M., Lau, H. C., Ho, G. T., & Wu, C. H. (2020). Evaluating the effectiveness of learning design with mixed reality (MR) in higher education. *Virtual Reality, 24*(4), 797-807. https://doi.org/10.1007/s10055-020-00427-9

Trowler, V. (2010). *Student engagement literature review*. Lancaster University, The Higher Education Academy.

Tscholl, M., & Lindgren, R. (2016). Designing for learning conversations: How parents support children's science learning within an immersive simulation. *Science Education, 100*(5), 877-902. https://doi.org/10.1002/sce.21228

Wang, J. (2001). *Handshakes in cyberspace: Bringing the cultural differences through effective intercultural communication and collaboration*. National Convention of the Association for Educational Communications and Technology, 513-519.

Weng, C., Rathinasabapathi, A., Weng, A., & Zagita, C. (2018). Mixed Reality in science education as a learning support: A revitalized science book. *Journal of Educational Computing Research, 57*(3), 777-807. https://doi.org/10.1177/0735633118757017

Yuen, S. C., & Yuen, P. K. (2008). *Mobile learning.* In L. A. Tomei (Ed.), Encyclopedia of information technology curriculum integration. Idea Group.

Yusoff, R. C. M., Ibrahim, R., Zaman, H. B., & Ahmad, A. (2011). Evaluation of user acceptance of mixed reality technology. *Australasian Journal of Educational Technology, 27*(8), 1369-1387. https://doi.org/10.14742/ajet.899

Zhan, T., Yin, K., Xiong, J., He, Z., & Wu, S.T. (2020). Augmented reality and virtual reality displays: perspectives and challenges. *IScience, 23*(8), 1-13. https://doi.org/10.1016/j.isci.2020.101397

Zheng, R.Z. (2020). *Cognitive and affective perspectives on immersive technology in education.* IGI Global.