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RESEARCH ARTICLE

The State of the Metaverse in Education: A Narrative Review of Trends, Applications, Challenges and the Emerging Role of Family–School Interactions

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Abstract
This study explores the evolving role of the metaverse in education, with a particular focus on emerging trends, pedagogical applications, and the transformative potential of family-school interactions within virtual learning environments. This study examined articles from January 2000 to May 2025 using a narrative review method. The statistical population of the study includes all studies conducted on education in the metaverse, and through content analysis, research trends, patterns, geographical distribution, opportunities, and challenges of education in the metaverse were examined. Through a comprehensive review, we identify three dominant trends: (1) increasing adoption of immersive technologies in STEM and arts education, (2) growing research interest post-pandemic, particularly in North America and East Asia, and (3) the development of multi-layered educational interactions (student-teacher, peer-to-peer, and parent-school). Key applications demonstrate the metaverse's capacity to enable borderless collaboration, personalized learning through AI analytics, and culturally inclusive educational experiences. The analysis reveals significant opportunities for family engagement, including real-time parental participation in learning processes and enhanced safety monitoring features. However, critical challenges emerge, including digital equity gaps (particularly in Middle Eastern and African contexts), privacy concerns, technological addiction risks, and special needs accessibility barriers. The findings suggest that while the metaverse offers innovative pathways for reimagining education, its successful integration requires addressing infrastructural limitations, developing ethical frameworks, and implementing targeted teacher and parent training programs. This review contributes to ongoing discussions about digital transformation in education by highlighting both the disruptive potential and implementation complexities of metaverse technologies in family-school ecosystems.

Keywords: Metaverse in Education, Virtual Learning, Family-School Interactions.

INTRODUCTION

With the declaration of the COVID-19 pandemic in 2020, humanity was forced to reduce social interaction in the physical environment (Koo, 2021). In particular, a wide range of activities in the physical world shifted to the virtual world, and remote work, online meetings, distance education, online shopping, etc., became a natural part of human life. As a result, the human need to expand the boundaries of the physical world accelerated, sparking a desire for a more advanced virtual world (Suzuki et al., 2020). Alongside the widespread adoption of virtual education, changes in learning methods attracted the attention of educational researchers, and engaging technologies such as video conferencing and the metaverse (a three-dimensional digital space) were implemented in education (Hyun & Park, 2020). According to the Technology Acceptance Theory (TAM), factors such as perceived usefulness, perceived ease of use, and user attitudes play a decisive role in the acceptance of these technologies (Toros et al., 2024).

The metaverse refers to a digital virtual world that connects our imagination to real life, where individuals can experience new things with their virtual avatars, create identities, live, learn, and work (Ng, 2022). Although virtual reality (VR) and augmented reality (AR) are often considered the foundational technologies of the metaverse, the concept of the metaverse extends beyond these technologies. In fact, the metaverse aims to create a new, inclusive socio-technical system with unique social and engineering features, such as persistence, simultaneity, and unprecedented interoperability (Hadi Mogavi et al., 2023). Education is widely regarded as one of the most promising fields for the application of metaverse technology (Han et al., 2023).

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Research findings show that the use of the metaverse in education has evolved over generations and can provide countless opportunities in language learning, mathematics, medical sciences, digital games, technology, healthcare, nursing skills, and other fields by exploring environments that have historically been inaccessible due to barriers of space, time, and cost (Kye et al., 2021; Hwang & Chien, 2022; Parmaxi, 2023). It helps learners develop teamwork, independence, and cultural awareness, practicing collaboration and data transfer between the physical and virtual worlds (Wang et al., 2022).

Given such opportunities, researchers have focused on aligning virtual reality with educational backgrounds and seek to better integrate these tools with teaching methods and learning instructions for comprehensive implementation in teaching practices (Han et al., 2023). Thus, the use of virtual reality is an essential skill and capability for 21st-century learners (Wang et al., 2022).

Along with these benefits, the use of digital technologies comes with numerous limitations and challenges including; powerful computational techniques for delivering the experience (Park & Kim, 2022; Bhattacharya et al., 2023). Mid-range mobile devices and internet connectivity in educational institutions (Chamorro-Atalaya et al., 2023). Problems such as cyberbullying, cybersecurity, inadequate instructional design, ethical issues, and legal constraints (Zhang, 2023).

While reviewing the available resources on the metaverse in education, the most noteworthy omission seems to be the role that families can play within this evolving education framework (De Felice et al., 2023). Many researchers have focused on the metaverse in relation to the pedagogy of teachers and students, and the academic outcomes, but the role of families and the dynamics of home-school relationships within these virtual environments remains largely unaddressed (Nuryana et al., 2024). There is no doubt that the research done in the context of conventional education have shown, time and again, active parental engagement is among the most significant determinants of a child's academic achievement (Muller, 2018).

There are some potential explanations for this oversight. To begin with, a large portion of the foundational studies on metaverses concentrated on the technical and infrastructural elements of this phenomenon and did not attend to the phenomenon's social and educational aspects (López-Belmonte et al., 2023). Also, in many educational cultures, families are regarded as passive participants and therefore their engagement in the learning process is minimal (Kelty & Wakabayashi, 2020). Lastly, inequitable access to modern technology has meant that scholars have studied the participation of families in lower-resourced communities less (Fazal et al., 2025).

As technology continues to expand, the metaverse is now being considered a virtual space for learning, with many arguing that it can reshape the interactions that happen between the home and school, perhaps forever. Parents can and will wish to participate in their children's learning in entirely different dimensions compared to the physical school setting. Nonetheless, very few studies have focused on the implications, and even fewer have focused on the challenges that come with it (López-Belmonte et al., 2023). Although the metaverse has the ability to democratize education, the way it is developing and progressing now is more likely to replicate the narrower gaps found in physical classrooms rather than expanding access to education for all (Zhang, 2023).

Very few studies examining the metaverse have delved into the family and school interaction and collaboration, even though the majority of parents and caregivers want more access and engagement in children's learning and digital education (Kye et al., 2021; Tlili et al., 2022). This lack of alignment is a call to redesign the metaverse not only as a space to educate but as a social system in which families, teachers, and students come together to design learning experiences. Fulfilling this gap is the goal of this article which, by compiling the existing piecemeal evidence, aims to answer the primary question: How can the metaverse change the educational relationships and what are the possible opportunities and challenges in this regard? This study aims to build the appropriate theoretical scaffolding for subsequent investigations by integrating the pre-existing fragmented evidence and offering a distinct analysis.

MATERIALS AND METHODS

This review focused on assessing information concerning the applications of the metaverse in the educational context, particularly the interactions between the family and school, using the narrative review methodology. The search for references was executed using the keywords "metaverse AND education", "virtual reality AND family-school interaction", and "3D learning AND parental involvement" in such databases as Scopus, Web of Science, PubMed, ScienceDirect, Google Scholar, Magiran, and Sid. Because of the nature of a narrative review, no time frame was particularly set for the inclusion of studies, although there was bias towards articles published between January 2000 and May 2025.

Inclusion and Exclusion

This narrative review is based on a critical analysis of scientifically rigorous studies that address the primary research question on the role of the metaverse in education, with a particular emphasis on family-school interactions. References that only addressed technical aspects of the metaverse or lacked an educational analysis were excluded. The selected literature was synthesized and grouped into four central themes: trends in the development of the metaverse in education, its educational applications, implementation challenges, and its specific role in facilitating family-school interactions.

Analytical approach

This narrative review employs a descriptive and critical blend. Initially, each study's key findings were systematically extracted, and later, an analytical approach presented in this review allowed for the evaluation of the literature's strengths, weaknesses, and gaps. This approach has balanced comprehensive and analytical, adding to the understanding of the state of research while indicating areas that need further exploration. However, because of the unsystematic nature of the narrative review, this study makes no claim of comprehensiveness. Its aim is to answer the questions arising from the subject through an in-depth analysis while focusing on the critical and indexed sources.

RESULTS OF STUDY

The findings section attempts to answer the research questions in order.

The Concept of the Metaverse

The idea of the metaverse was previously heard in science fiction novels like Snow Crash (Stephenson, 1992) and gained mass attention with the film adaptation of the novel Ready Player One and Second Life (Wiederhold, 2022). The term "metaverse" is a combination of the prefix "meta," meaning "beyond," and the word "universe," describing a parallel or virtual environment connected to the physical world.

The metaverse is a term used to describe a shared collective virtual space where users can interact with a computer-generated environment and with each other in real-time. In its initial concept (Stephenson, 1992), the metaverse served as a place to escape daily life and experience something new. Since then, the concept has evolved, and with technological advancements, it has now become a reality. Since the early 2000s, a small number of researchers have often used the term "metaverse" to describe technologies and infrastructure development for Second Life systems (Ng, 2022). The metaverse was initially described as a virtual world accessible via computers and VR headsets. However, it has undergone significant changes compared to its earlier versions, which can be categorized into three distinct groups (Park & Kim, 2022):

1. The first significant change is the rapid development of deep learning, which has significantly improved visual and language recognition accuracy, creating a more immersive and natural environment. Additionally, multimodal metaverse models have helped reduce processing time and complexity, resulting in more efficient end-to-end solutions.

2. The second change is the evolution of the metaverse from larger computers for access to internet-connected mobile devices, allowing users to access it anytime and anywhere.

3. The third significant change in the metaverse is the ability to program in the metaverse, linking it more closely to real life with virtual currency. Cryptocurrencies act as an economic bridge between the metaverse and the real world, giving it deeper social meaning (Tavana & Sorooshian, 2023).

Research Trends in the Metaverse

Figure 1 illustrates the research trends in metaverse-based education. According to the presented data, the number of published papers in this field has shown an upward trajectory from 2000 to 2025. In the early years of this period, from 2000 to 2018, the number of publications remained relatively low, ranging between 2 to 10 papers annually, indicating limited research attention to this topic during those years.

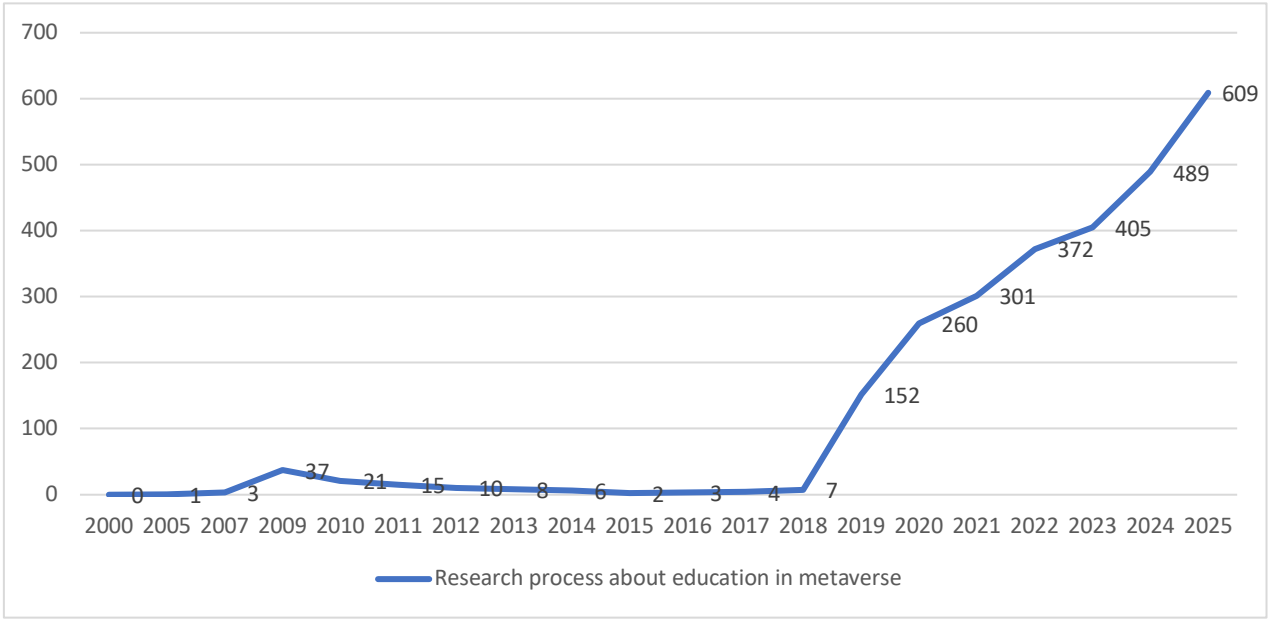

Figure 1. chart illustrates the research trends in metaverse-based education

As we approached 2019, a gradual increase in publications became noticeable, reaching approximately 100 papers that year. This growth was likely influenced by technological advancements in virtual and augmented reality. However, the most significant turning point occurred in 2020, coinciding with the COVID-19 pandemic, when the number of papers dramatically surged beyond 200. This sudden spike can be attributed to the shift from traditional classroom education to virtual learning environments and the heightened focus on innovative educational technologies.

Following 2020, this upward trend continued with a steep incline: approximately 301 papers in 2021, around 372 in 2022, and exceeding 405 in 2023. This sustained growth demonstrates the consolidation of the metaverse as a significant research area in education. Projections suggest this trend will persist through 2025, with the number of publications expected to reach about 700 papers - representing an approximately 70-fold increase compared to the year 2000.

Distribution of Metaverse-Based Education in Countries

When examining the country of affiliation of the first author, the United States has the highest number of studies, followed by Brazil, Japan, Spain, and South Korea. Interestingly, our search criteria did not reveal any studies on the role of the metaverse in family-school interaction in African and Middle Eastern countries up to 2022. This

could be due to the limited infrastructure that these countries suffer from and the lack of facilities that do not support technology-based learning environments. As a result, the question arises whether this type of learning environment does not exacerbate the digital divide rather than reducing it and ensuring inclusive education? Of course, after 2022, studies on the metaverse have increased exponentially in China, and this has also been observed in Middle Eastern countries.

Fields of Education in the Metaverse

According to Figure 2, the fields of basic sciences (mathematics and natural sciences) have made the most use of metaverse capabilities, with a share of 53%. This remarkable success is largely due to the metaverse's ability to simulate advanced virtual laboratories, visualize abstract mathematical and physical concepts, and allow for complex experiments without safety constraints or high equipment costs.

General education is next with 15% and art with 11%. In general education, the metaverse enables collaborative learning and problem-solving environments, while in art, the technology allows students to present their work in international virtual galleries and benefit from global feedback.

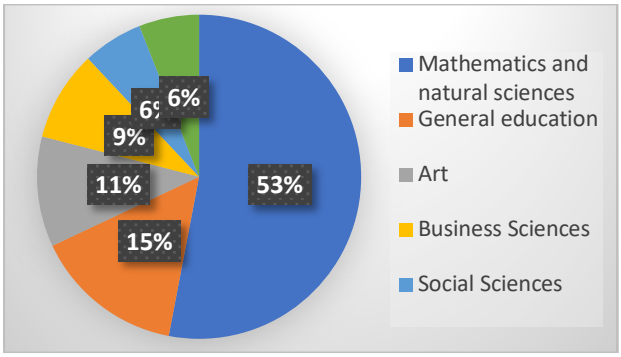

Figure 2. Fields of Education in the Metaverse

Interestingly, the relatively low share of business sciences (8%), social sciences (7%), and aircraft maintenance (6%). This may be due to several factors, including; these fields' lower need for advanced 3D simulation; The natural delay in the adoption of new technologies in the humanities; and the lack of appropriate educational content for these fields in the metaverse environment. Therefore, future research could focus on these educational fields to provide learning experiences for more disciplines.

The Impact of Metaverse Applications in Education

According to Figure 3, which shows the impact of metaverse applications in education, three categories were identified: academic performance, interpersonal interaction, and learner satisfaction. However, to a large extent, the reviewed academic articles indicate that researchers have focused their studies on the factor of academic performance, accounting for 62%, while studies focusing on interaction and improving communication skills among students through metaverse applications account for 38%.

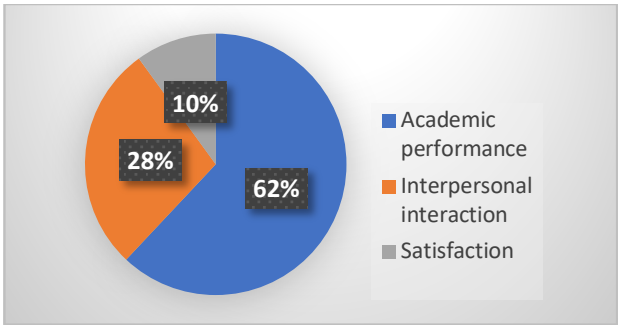

Figure 3. Dimensions of the impact of the metaverse on learners

Emerging Trends in Metaverse-Education Integration

A review of the research literature on the metaverse in the context of education reveals that the said technology is creating a paradigm shift in the global education system, which can be grouped into three major trends.

Trend 1: Greater Embracing of Pervasive Technologies into STEM and the Arts.

The findings of the content analysis revealed that 53% of the research conducted within the metaverse's context focused on the basic science, technology, engineering and mathematics (STEM) fields. The reasons for this popularity are multifaceted. For one, the 3D realms of the metaverse enable the simulation of sophisticated virtual laboratories where students can undertake sophisticated experiments without the constraints of safety concerns or expensive equipment. Moreover, these realms facilitate the visualization of abstract mathematical and physical concepts. Notably, 11% of the research focused on the application of metaverses in art education, which is notable since these spaces enable students to showcase their artworks in virtual galleries and receive global feedback.

Trend 2: Major increase in research after COVID-19

The number of scientific articles in this area increased from 156 in 2019 to 405 in 2023. This increase has been most notable in North America and East Asia. Analysis suggests the COVID-19 pandemic served as a stronger catalyst for this increase as schools and universities were forced to find alternatives to in-person learning. Interestingly, 68 percent of these studies focused on the advantages of the metaverse for maintaining educational continuity during times of crisis.

Trend 3: New Patterns of Interaction Start to Emerge as a Result of the Metaverse.

The use of the metaverse has a profound impact on the educational paradigm. The changes can be grouped into 6 categories (Zhang, 2023):

1. Teacher-Student Interaction: this is the most traditional and basic type of teaching interaction. It happens between a teacher and a single student or a group of students and is characterized by the delivery of information, answering questions, and feedback. Students respond by asking questions, participating in discussions, and completing assignments.

2. Student-Student Interaction: This level of educational interaction involves collaboration among students for learning and problem-solving, which can take the form of group discussions, collaborative projects, and peer assessments. Student-student interaction can be particularly useful for promoting critical thinking and problem-solving skills.

3. Student-Content Interaction: This level involves students interacting with course content, such as textbooks, multimedia resources, and online quizzes, which may include reading, watching, listening, and engaging with the content to gain a deeper understanding.

4. Teacher-Content Interaction: This level involves teachers interacting with course content to develop lesson plans, select resources, and design assessments. It is crucial for ensuring the content is relevant, engaging, and aligned with learning objectives.

5. Student-Environment Interaction: This level involves students interacting with the physical or virtual learning environment to complete assignments and engage with course content, which may include working in classrooms, labs, or online learning platforms.

6. School-Family Interaction: This level can influence other parts of the learning interaction process, engage learners in learning, and involve families in educational activities.

The metaverse has created new possibilities for interfacing with teachers, students, and families regarding communication and interaction patterns. One notable finding is the development of the "three-way collaborative classrooms" whereby parents can partake in their children's education remotely. This approach has notably enhanced learning outcomes, particularly in the science and art skill-based education sectors. Studies indicate that parents engaging with teachers and students in a metaverse environment can enhance learner participation (Xu et al., 2024; Tlili et al., 2022).

Advantages of Family-School Interaction in the Metaverse

The metaverse offers a transformative platform for family-school collaboration by transcending physical barriers, allowing parents and educators to meet in a shared digital space through VR headsets. This accessibility increases parental engagement from home or work, fostering a more invested role in their children's education. A significant advantage is the enhanced safety and control; educators and parents can mitigate risks like bullying through adjustable permissions, creating a secure environment conducive to learning.

Furthermore, dispersing students to their homes rather than congregating in a single physical space precludes catastrophic events such as school shootings. The metaverse also empowers families with deep, data-driven insights into their child's learning. Through AI and advanced algorithms, it analyzes individual strengths, weaknesses, and styles to deliver personalized education, enabling parents to make informed decisions based on their child's specific needs. This digital interaction naturally promotes cultural understanding and respect for diversity by connecting students with global peers, broadening horizons and celebrating a wide range of perspectives. Finally, it establishes a foundation for lifelong learning, serving as an engaging platform for the continuous skill development of both students and their families (Alfaisal et al., 2024).

Challenges and Limitations of Family-School Interaction in the Metaverse

Despite its potential, the integration of the metaverse for family-school interaction faces several significant limitations. A primary barrier is the digital divide, as equitable access to the required technology, notably VR headsets, is not universally available, threatening to restrict this educational model to a privileged few who can afford it. This issue of access is further compounded for children with disabilities, who may require special accommodations (such as those for hearing or vision impairments) that families cannot provide and schools, especially in cross-border scenarios, may be unwilling or unable to implement. Even when access is secured, critical risks emerge, including the potential for metaverse addiction, where excessive use could lead users to neglect real-world responsibilities and disrupt the essential balance between digital and physical life. Furthermore, serious concerns regarding privacy and data security threaten families with exposure to cyber threats, eroding trust in these platforms. Finally, heavy reliance on virtual interaction poses a risk to the development of authentic real-world social skills, a challenge that educators and technologists must proactively address to ensure a holistic educational experience (Briceño, 2022).

DISCUSSION

Results of this narrative review provide several perspectives regarding the changing features of metaverse technology in education within the scope of family-school relationships. The synthesizing of the results from the studies reveals the following three notable trends: (a) improved use of immersive technologies in the teaching of STEM subjects and the arts, (b) heightened emergence of research activity during and after the pandemic, notably in North America and East Asia, and (c) the emergence of multi-layered educational engagements (student-teacher, peer-to-peer, and parent-school interactions). As Lepez (2022) points out, the metaverse offers the potential of enriching the learning experience using immersive methods such as virtual reality.

The most notable finding is the significant surge in metaverse education research in the metaverse following the COVID-19 pandemic. That moment in time was clearly pivotal, as the number of research publications in the area skyrocketed to 200 articles in 2020. This was most likely the result of an urgent need to replace in-person education with something more feasible. This sharp increase demonstrates the remarkable ability of education systems to respond to challenges and crises through innovative technologies. However, the significant increase in research output in this area raises some critical concerns, particularly the balance between quantity and quality of the output. To begin with, the geographical distribution of this research is quite disproportionate, with more than 80% of the research emanating from the developed nations of North America and East Asia. Meanwhile, developing countries, and in particular those from the African and Middle Eastern regions, have a vanishingly small share. This inequity in research productivity risks developing

solutions that do not address the realities of the less developed education systems.

Another important finding is the disproportionate growth in metaverse adoption for STEM education (53% of studies) compared to other disciplines. This disciplinary gap suggests that pervasive technologies are prioritized for subjects that can provide tangible educational benefits, such as laboratory simulations and 3D modeling. However, the relatively lower adoption in social sciences (7%) and vocational education (6%) indicates the need for more discipline-specific metaverse applications that address the unique learning goals of these fields.

Regarding interaction patterns, the metaverse enables new forms of interaction between teachers, students, and families. The emergence of "three-way collaborative classrooms," where parents can actively participate in their children's learning process virtually, represents a significant development. Key benefits of this system include greater parental monitoring of academic progress through real-time analytical tools and the removal of geographical barriers, enabling participation by families who cannot physically attend school due to migration or work commitments (Xu et al., 2024).

Nevertheless, substantial challenges remain. The most critical is the "digital divide" that excludes low-income families from accessing this technology. Another challenge comes from teacher resistance, as many educators feel inadequately prepared with the technical skills required for metaverse classroom management. Additionally, cultural differences in technology acceptance present obstacles, as families in cultures that highly value face-to-face interaction express concerns about replacing physical with virtual engagement (Zhai et al., 2022). These findings underscore that successful metaverse implementation in education requires simultaneous attention to technical, cultural, and social dimensions.

CONCLUSIONS AND RECOMMENDATIONS

This review demonstrates the impact of the metaverse on the education systems of the world. It has been established that the technology creates novel methods of educational interaction for individualized learning, global collaboration, and active learning engagement of families. Nonetheless, the lack of digital accessibility, privacy issues, cultural barriers, and limited availability continue to hinder its adoption. In particular, the lack of focus on the impact of families and the overwhelming concentration on developed nations are considerable gaps in the literature.

Thus, to effectively harness the metaverse's educational potential, a holistic approach integrating the technical, cultural, and societal aspects of the technology is vital. Remote and local solutions, development of ethical frameworks, infrastructure investment, and education of relevant stakeholders are immediate prerequisites for leveraging the technology. Ultimately, its integration in education will succeed if the metaverse is used as an enrichening tool alongside traditional modalities and thoughtful equilibrium is established between technological prowess and human requirements, especially the meaningful involvement of families and parents.

These studies had several limitations. Despite the extensive literature review, most of the studies analyzed were from developed countries in North America and East Asia. This limits the generalizability of the findings to other cultural and educational contexts, especially in developing countries. Also, few studies have examined the needs of students with different abilities or from low-income families, while these groups are most vulnerable to digital changes.

Accordingly, it is proposed. Designing metaverse-based educational models that are compatible with the cultural and infrastructural characteristics of developing countries. Different geographical contexts are to be considered. And practical solutions and the possibility of using metaverse systems to personalize learning and provide intelligent feedback to parents in metaverse environments.

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Competing interest

The authors assert that no competing interests exist.

Consent for publication

All authors agree to submit the article to the journal and grant copyright.

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ADDITIONAL INFORMATION

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