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Assistive Technology for Distance Education in Metaverse-Based Environment: A Rapid Review

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Abstract. *Metaverses offer immersive virtual realities with potential applications in distance education. Integrating metaverse with assistive technology enables educational advancements and inclusive participation. This paper aims to gather evidence on metaverses, assistive technologies, and distance education. We conducted a Rapid Review analyzing seven studies out of 145 initial bases. As preliminary results, Chemistry Lab was the main focus (42.5%), with evaluation research as the primary strategy (57.1%). The challenges included instrumentation, technical issues, complex systems, student performance, presence, and accessibility assessment. The findings may aid researchers and practitioners in designing inclusive educational experiences in the metaverse.*

1. Introduction

Assistive technologies (AT) play a vital role in the daily practice of virtual learning environments (VLE), triggering significant educational transformations. The integration of information technology in education has been crucial to enhancing students' access and participation, regardless of their abilities or limitations. AT is a term used to identify the arsenal of resources and services that contribute to providing or expanding the functional abilities of people with disabilities (PwD) and, consequently, promoting their independent life and inclusion [Bersch 2008]. The emerging interest in studies on ATs is notorious, both about conceptualization and the relative emphasis on autonomy, independence, and improvement of the performance of the people contemplated by them [Ramos Baleotti and Dutra Zafani 2017, Soares et al. 2017]. When referring to the care of PwD, this relevance increases as we observe that, in addition to the benefits described in the literature, technologies are also an essential tool in the process of resocialization and the search for the exercise of citizenship [de Jesus Alves and Matsukura 2014, Bersch 2013]. Complementing, Nishar and Rahman (2006) state that a Learning Management System (LMS) is a high-level strategic solution to plan, provide and manage all learning events of an organization, including online courses, virtual classroom classrooms, and Distance Education (DE).

According to Abbad (2007) , DE is a modality linked to open, lifelong, or continuous learning. E-learning has taken on a crucial role in expanding online education systems. Moreover, numerous universities have actively engaged in creating and enhancing online tools. In Europe, they promote and support the Massive Open Online Courses (MOOC) initiative [Wiak et al. 2012] and the use of the Modular Object-Oriented Dynamic Learning Environment (Moodle) in different parts of the world [Sabbatini 2007].

The emergence of a term known as emergency remote teaching (ERT), which gained prominence with the COVID-19 outbreak, is worth noting."Remote" means far in space and refers to geographical distance. Teaching is considered remote because teachers and students are prevented by decree from attending educational institutions to prevent the spread of the virus. It is an emergency because the pedagogical planning for the 2020 school year had to be suddenly shelved [Behar 2020]. Considering the specificities of both DE and ERT, Dahan et al. (2022) highlight that metaverse applications, which are one of the educational opportunities under development, allow their users to have virtual learning experiences interactively through their technological resources.

Tas and Bolat (2022) point out that metaverse technology has potential for education and that the institutions and companies involved must explore it. Metaverse is a combination of "meta" (meaning beyond) and the "verse" from "universe", denoting the next-generation Internet in which the users, as avatars, can interact with each other and software applications in a three-dimensional virtual space [Davis et al. 2009, Duan et al. 2021, Dionisio et al. 2013]. Metaverses are immersive three-dimensional virtual worlds (VWs) where people interact with each other and their environment, using the real-world metaphor but without its physical limitations [Owens et al. 2011, Owens et al. 2009].

This paper aims to gather, organize, and analyze available evidence in the literature and research trends on metaverse, assistive technologies, and DE. To achieve our proposed goal, we conducted a Rapid Review (RR) [Cartaxo et al. 2018] since it has core characteristics that: 1) reduce the costs of heavyweight methods, 2) delivers evidence promptly, 3) operates in close collaboration with practitioners, and It reports results through appealing mediums [Tricco et al. 2015]. The mentioned aspects are relevant to our context as the first author, a professional in a company specializing in creating innovative and accessible solutions for diverse groups, including DE and assistive technologies, seeks to gain initial insights into integrating the metaverse alongside both these concepts.

Our RR findings indicate that most proposals were published in Journals (57%) between the years 2020 and 2023. The Chemistry Lab context was the main focus of most studies, comprising three studies (42.5%). Most returned studies employed evaluation research (57.1%) as their research strategy. Empirical experiments were conducted in 42.8% of the studies, and the quality-quantitative method was applied in 71.4%. Regarding the challenges of implementing accessibility in the metaverse, we highlighted the instrumentation, technical problems, complex systems, student performance, sense of presence, and accessibility assessment. Finally, we generated an *Evidence Briefing* [Cartaxo et al. 2016] based on our findings to make the RR more appealing to practitioners.

2. Background and Related Works

Lin et al. (2022) explore integrating traditional education with Web 2.0 through MOOCs, highlighting certain limitations, such as the lack of engaging content and low student participation. Recognizing the imminent arrival of Generation Z, who are familiar with online education, preparing for a new revolution in educational models becomes crucial. Leveraging the potential of the metaverse can be particularly beneficial since it offers interaction, authenticity, and immersive experiences. According to Fernandes and Werner (2022), the metaverse is a new paradigm under construction where social, immersive Virtual Reality (VR) platforms will be compatible with several kinds of applications.

In this context, applications of this metaverse must serve as relevant tools for PwD. Ball (2022) emphasized the importance of ensuring the metaverse is accessible to individuals with disabilities, recognizing them as valuable contributors. However, he did not specify any particular disability or explain how accessibility and inclusion should be effectively achieved. In this direction, there is a conceptual highlight of AT as an association between products and services, considering that these are associated with both the need for information accessibility and physical accessibility [Vianna and Pinto 2017].

In this regard, we analyzed related works that have proposed revisions to examine research trends on the metaverse, assistive technologies, and DE. Alfaisal et al. (2022) evaluated 41 research studies published between 2011 and 2022, examining the applications of education in the metaverse utilizing information systems (IS) models. The authors identified the Technology Acceptance Model as the predominant approach for predicting metaverse adoption and SmartPLS as a tool to validate metaverse models.

Subsequently, Onggirawan et al. (2023) conducted a systematic review to evaluate the advantages and disadvantages of virtual educational spaces in the metaverse. The findings revealed that students prefer using the metaverse for learning and achieve better comprehension than traditional approaches. However, further research is needed to determine the preferred disciplines and appropriate educational levels for Metaverse-based teaching. Notably, the metaverse holds significant educational potential, but guidance from teachers and parents is crucial in addressing potential drawbacks.

Fernandes and Werner (2022) provide an overview of research on accessibility in immersive systems, specifically focusing on the metaverse. The researchers aimed to identify challenges and opportunities for the Human-Computer Interaction community to enhance the inclusion of individuals with disabilities in this evolving environment.

The studies explored metaverse and education [Alfaisal et al. 2022, Onggirawan et al. 2023], and metaverse and accessibility [Fernandes and Werner 2022]. Unlike these studies, our review considered the three pillars together to understand how accessibility is being considered in metaverse-based distance learning environments. In addition, we identify open challenges to meet practitioners' perceptions in a real-world environment and support researchers by pointing out study possibilities to assist PwD.

3. Rapid Review Protocol

As illustrated in Figure 1 and detailed in the following, this section presents the Rapid Review (RRs) protocol based on [Cartaxo et al. 2018].

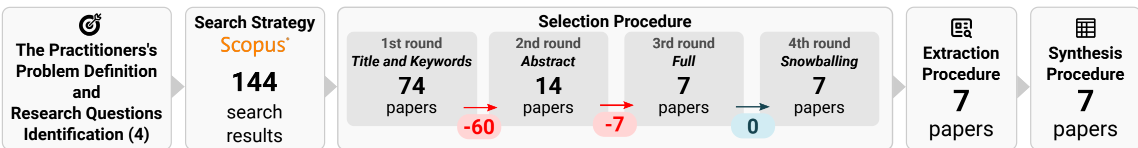

Figure 1. Rapid Review Protocol.

This type of secondary study aims to provide practitioners with timely evidence and facilitate the transfer of established knowledge into practice since RRs contribute to 1) cost reduction compared to heavyweight methods; 2) timely delivery of evidence; 3) close collaboration with practitioners; 4) reporting results through engaging mediums.

In addition, we applied quality evaluation in the studies to analyze the empirical validation [Kitchenham et al. 2009b]. In this sense, based on the **practitioners' problem**, which aimed to answer "*How have metaverse applications with accessibility in distance education been proposed?*" and to substantiate the assumptions within time and cost constraints, the authors conducted this RR to gain relevant initial insights. In this regard, we formulated four **research questions (RQ)** to guide our research:

- **RQ1)** How has the publication of primary studies evolved over the years?
- **RQ2)** What domains are being explored in studies addressing accessibility in DE within the metaverse context, and how are they approaching it?
- **RQ3)** What challenges are associated with implementing accessibility in educational metaverse platforms?
- **RQ4)** What research and empirical strategies and methodological approach are being used?

Regarding the **search strategy**, to expedite the process of finding primary studies and *reduced costs*, such as proposed by [Cartaxo et al. 2018]. For example, we limited the search strategy by publication date (2018-2023) and exclusively utilized the Scopus[1] search engine. This search engine encompasses numerous highly regarded digital libraries within the software engineering field. Three keywords were identified based on the defined research questions: `metaverse AND accessibility AND distance education`. We added synonymous to each group of these words to encompass a more significant number of studies available in our support repository [Damasceno et al. 2023]. We obtained 144 search results from the automatic search mechanism executed in June 2023.

After discussing with the authors and validating with the practitioner regarding their industry interests, the **selection procedure** was based on the following criteria: C1) the study must be contextualized within the metaverse; C2) the study must be focused on DE within the metaverse; C3) the study must address accessibility in the metaverse; C4) the study must be in English, and C5) the study must be available. Since the concept of the metaverse is still evolving and encompasses other technologies, such as VR, we emphasized that in C1, C2, and C3, the metaverse concept should align with at least one defined in Ritterbusch and Teichmann (2023) . These criteria were applied during the initial three rounds of selection. Two researchers independently reviewed the *titles* and *keywords* of the studies in the ***1st round*** (72 papers for each). Studies that did not meet the criteria were excluded, resulting in 74 studies. The same procedure was followed in the ***2nd round***, considering the *abstracts*, which resulted in 14 studies. In the ***3rd round***, an individual researcher analyzed the full papers' content by applying the criteria. This process culminated in selecting a final set of seven primary studies. Finally, we used a snowballing backward and forward in the ***4th round***, which did not return studies that satisfied the criteria applied in 1st and 2nd rounds.

Related to the **extraction procedure** and **synthesis procedure**, we initially carried out a simplified process called *keywording* [Petersen et al. 2008] encompassed the following steps: (1) Randomly selecting three pilot studies as an initial sample; (2) Examining the complete texts of these studies to extract relevant keywords and concepts; (3) Organizing the collected keywords and concepts into emerging categories, forming the ini-

[1]https://www.scopus.com/

tial classification structure (e.g., problem target, associated technologies); (4) Analyzing each primary study thoroughly and extracting pertinent information in accordance with the predefined classification parameters; (5) Refining the classification structure through collaborative discussions, incorporating additional information obtained from the primary studies. We organized the extracted information by category on a *Google Spreadsheet*.

RRs are typically more susceptible to **threats to validity** than other reviews due to their lightweight methodology, including: (1) utilizing a single indexer (Scopus) for the search engine, which may limit the number of relevant primary studies; (2) some stages of the selection being conducted by a single researcher, potentially introducing selection bias; (3) the keywords used in the search string may not have been comprehensive enough to encompass new studies; (4) most authors have more experience in academia, providing a possible bias in identifying more scientific evidence than practice. Finally, to mitigate the 4^{th} threat to validity and make the RR more appealing to practitioners, we summarized the RR in an Evidence Briefing [Cartaxo et al. 2016] as a **RR report**, a one-page document presenting the main findings available in our support page [Damasceno et al. 2023].

4. Results and Discussion

4.1. *RQ1) How has the publication of primary studies evolved over the years?*

Figure 2 depicts the distribution of the selected primary studies based on their publication year and type (Journal or Conference). We can observe the studies primarily fall into recent years, starting from 2020, indicating the growing interest in the metaverse during this period. The frequency of publications did not surpass one study per year in 2021 and 2022 and up to the present date in 2023. Regarding publication type, 28.5% of the studies were published in Conferences (2), while 57% were published in Journals (5). It is worth noting that only the year 2020 featured both publication types, with two studies each.

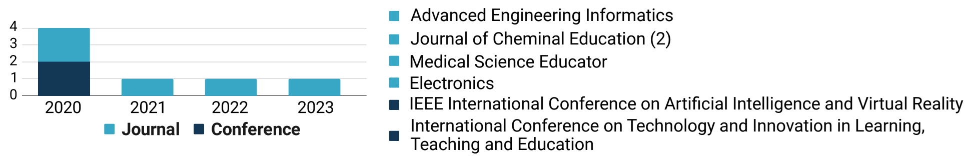

Figure 2. Number of papers over the years and the publication type.

Only one conference mentioned "Virtual Reality" suggesting the inclusion of related fields. The limited number of studies reflects the use of the RR protocol and underscores the identified gap in discussions on accessibility in DE within the metaverse. This conclusion is supported by the pilot searches conducted, which yielded many studies when considering education and the metaverse as standalone topics. However, incorporating the keywords of accessibility significantly reduced the number of relevant studies.

4.2. *RQ2) What domains are being explored in studies addressing accessibility in DE within the metaverse context, and how are they approaching it?*

We also identified the business contexts explored in the primary studies from the data extraction. Most of the studies focused on the Chemistry Lab context, comprising three studies (42.5%). The other contexts had only one study, including Accessibility Assessment of eLearning Tools, Construction Education, Medicine, and Collaborative Learning.

In the context of **Chemistry Lab**, Dunnagan and Gallardo-Williams (2020) proposed a set of VR experiments for organic chemistry labs as an online substitute for the in-person Organic Chemistry I laboratory. To overcome the sudden COVID-19, the authors initiated this project by demonstrating that certain students may be unable to attend the lab physically, including those with temporary or permanent disabilities. In this sense, they provided an alternative for students seeking accommodations that would prevent them from being physically present in the lab, addressing accessibility challenges. The researchers briefly discussed how they overcame the circumstances and shared their experiences with other institutions through open access. Extending this theme, Williams *et al.* (2021) also focused on students enrolled in an online Organic Chemistry laboratory course in VR, specifically those with documented disabilities or those who proved their inability to attend a traditional lab. Their objective was to investigate how students' expectations in the VR course aligned with their actual experiences. The authors utilized the "Meaningful Learning in the Laboratory Instrument" to assess students' pre- and post-course agreement with the cognitive, affective, and cognitive/affective dimensions of learning.

Considering the challenges faced by individuals with disabilities (wheelchair users) in using VR, Qorbani et al. (2022) focused on examining the effect of software controllers on accessibility in a VR chemistry testing laboratory to conduct the comparison. The study involved two groups (wheelchair users vs. non-wheelchair users), where participants had to use two types of accessibility features to complete tasks requiring body lowering or lifting. Results showed that the accessibility feature helped wheelchair users complete the activities with comparable outcomes to non-wheelchair users regarding completion rate, accuracy, and learning. The results also demonstrated that immersive VR environments have the potential to enhance accessibility.

Considering the thematic **Accessibility Assessment of eLearning Tools**, Cruz *et al.* (2022) explored how accessible Three-Dimensional Virtual Worlds (3DVW) or Second Life is as an eLearning tool by students with impairments. The authors evaluated and compared the accessibility between Second Life and Moodle tools using the Web Content Accessibility Guidelines (WCAG) since there are no tools to assess the accessibility of 3DVW. In addition, these guidelines covered different principles, such as adaptable, distinguishable, navigable, understandable, readable, perceivable, robust, and others.

Related to the **Construction Education**, Sun *et al.* (2022) proposed a collaborative virtual space where groups of students can easily and repeatedly visit previously inaccessible, dangerous, or expensive locations. Based on this, the authors sought to understand whether visits to the online virtual site lead construction students to achieve higher levels of learning performance, sense of presence, and social presence compared to the use of online business videoconferencing tools. Additionally, the researchers evaluated whether the proposal offers optimal system usability and a low-fatigue experience.

Considering the **Collaborative Learning** theme, Jovanović and Milosavljević (2022) introduce a novel VoRtex platform to provide an educational experience in virtual worlds. The platform aims to support collaborative learning activities and address the challenges brought about by the pandemic. Through a comparative analysis, the researchers evaluate the VoRtex prototype alongside other popular virtual world platforms, assessing the potential of VoRtex for online education. Following an interactive platform demonstration, participants were invited to complete a questionnaire to identify the key advantages of online teaching using Vortex. The authors also examine the benefits and drawbacks of collaborative learning between the metaverse and traditional classroom.

In **Medicine**, Brown et al. (2023) investigated the role of VR in DE through a large-scale online course on human anatomy. Overall, the virtual classroom maintained the rigor of traditional macroscopic anatomy labs without negatively impacting students' exam scores and provided a high level of accessibility without compromising student engagement. Exciting findings included students' appreciation for unique aspects of the software that were not replicable in a physical cadaver lab, such as the ability to scale and isolate anatomical systems in the virtual cadaver. This suggests that VR offers unique benefits as a novel instructional tool in human anatomy and indicates equivalent retention of anatomical spatial relationships between instructional modalities.

4.3. *RQ3) What challenges are associated with implementing accessibility in educational metaverse platforms?*

We identified gaps in the primary studies regarding accessibility in the Metaverse. One significant challenge is the issue of **instrumentation**. Dunnagan and Gallardo-Williams (2020) faced difficulties providing VR viewers for all enrolled students. These resources are crucial for student learning in DE, especially for students with disabilities. In the Metaverse, which incorporates VR and augmented reality (AR), ensuring the availability of necessary resources, equipment, and appropriate guidance becomes a pertinent requirement. Most metaverse systems need high graphic processing power and computational resources, leading to **technical problems** such as inconsistent audio, low-resolution visual content (visual quality), fluctuating bandwidth, and internet connection issues. These problems can directly impact sensory perception, including hearing and vision. Consequently, students need to navigate these variables and receive proper guidance in DE.

Dunnagan and Gallardo-Williams (2020) found that students perceived the system as "*unnecessarily complex*". **Complex systems** can hinder user-friendliness, necessitating a steep learning curve for students to utilize the equipment effectively. Consequently, an ill-equipped system for individuals with disabilities can result in visual and social fatigue, negatively affecting **student performance** in online classes. Another factor that may be affected by these issues is the **sense of presence**, which supports students' understanding of information interpretation in 2D and 3D. In this regard, students' affective learning may contribute more strongly to a meaningful learning experience, with cognitive and cognitive/affective elements also playing a role in meaningful learning [Williams et al. 2021].

Out of the analyzed studies, only Cruz *et al.* (2022) conducted an accessibility evaluation of a 3D virtual world tool (Second Life). To assess the adequacy of metaverse systems' accessibility, it is essential to have specific evaluation tools tailored to this context. Although Cruz *et al.* (2022) employed WCAG 2.0/2.1 for their evaluation, these guidelines primarily focus on web applications and may be ineffective for Metaverse. Consequently, selecting an appropriate evaluation tool requires considering various factors, including the application domain, pedagogical aspects, physical resources, logistics, and more. In this context, **combining different types of evaluations** may be necessary.

4.4. *RQ4) What types of research and empirical strategies are being used?*

In the following, we illustrated the results related to the research strategy (Figure 3a), empirical research (Figure 3b), and methodological approach (Figure 3c). The obtained responses to this question allowed us to identify that the majority of the returned studies employed evaluation research as their *research strategy* (57.1%). Meanwhile, validation research (28.6%) and personal experience papers (14.3%) were also utilized. We applied a checklist defined by Wieringa et al. (2006) to assess the quality of the research strategy. The results indicate that 75% scored above 50% on the quality criteria among the studies that adopted evaluation research. For studies employing validation research and personal experience papers, half of them achieved a score above 50%, each.

Regarding *empirical research*, 42.8% of the studies employed experiments, while case studies (28.6%) and general questions (28.6%) were also utilized. We used a checklist used by [Damasceno et al. 2019] and based on [Kitchenham et al. 2009a, Linåker et al. 2015, Runeson et al. 2012, Wohlin et al. 2012] to assess the quality of the empirical studies. The results indicate that all studies that employed experiments scored above 50% on the quality evaluation criteria. Half of those that employed case studies scored above 50%. All of the studies that employed general questions scored below 50%. Related to the *methodological approach*, we identified that 71.4% of the studies applied a quali-quantitative approach. At the same time, quantitative and qualitative methods were employed in 14.2% of the studies, each of the approaches. In this regard, we point out the relevance to advance in the field since it is necessary that more studies effectively solve the challenges and improvements of accessibility to the integration of metaverse and DE.

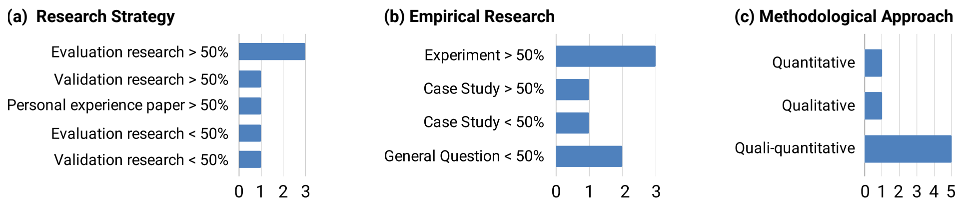

Figure 3. Research Strategy, Empirical Strategies, and Methodological Approach.

5. Open Challenges

5.1. Emergency remote teaching vs. Distance education

Most primary studies we analyzed mention the COVID-19 pandemic [Sun et al. 2022, Williams et al. 2021, Dunnagan and Gallardo-Williams 2020, Brown et al. 2023]. In this context, which solutions use metaverse for emergencies? Are there differences in the use of the metaverse for each type of teaching? Implementing the metaverse in emergency remote teaching and DE presents distinct challenges. In ERT, the primary challenge lies in swiftly transitioning to a virtual environment while adapting the curriculum and instructional practices to an online format. Furthermore, providing sufficient technical support to educators and students ensures a seamless and effective transition. The limited familiarity of both teachers and students with virtual tools and technologies poses an additional challenge that necessitates appropriate training and qualification initiatives. DE's challenges revolve around establishing an engaging and interactive online learning environment. It is imperative to cultivate student motivation and engagement despite physical separation.

Facilitating meaningful interaction between students and professors becomes more demanding due to the absence of face-to-face contact. Additionally, assessing student performance and guaranteeing the quality of teaching present ongoing challenges that require attention and resolution. COVID-19 motivated profound transformations in the educational field, accelerating changes related to the use of new technologies for students and teachers and being forced to attend remote environments constantly and adapt educational practices to them. With the gradual return to face-to-face activities after the critical period of the pandemic, students and teachers faced the growth of a challenging reality, hybrid teaching and learning [de Classe et al. 2023]. In this context, what would be the use of technologies as the metaverse to this type of teaching? Would it be a new challenge? It is a natural approach, a trend toward a new educational paradigm.

5.2. Industry involvement and practical application

This RR aimed to provide insights primarily to industry practitioners seeking to comprehend the evaluation of such environments, the technologies employed, and potential approaches for identifying the most suitable solution, considering the specificities of the metaverse-based DE platform. Implementing the metaverse in education entails utilizing diverse technologies to deliver immersive and interactive learning experiences.

Dunnagan and Gallardo-Williams (2020) express their intention to maintain the website open and accessible to anyone interested in utilizing the VR organic chemistry labs. Furthermore, VoRTex represents another valuable resource for supporting practitioners seeking to implement metaverses for educational purposes. VoRtex is an accessible open-source solution developed using a contemporary technology stack and metaverse concepts. The source code for VoRTex can be accessed on GitHub[2]. Given this understanding, practitioners could carry out research activity in collaboration with a team with expertise in pedagogy to understand how the area of pedagogy evaluates the impact of the application as teaching tools, including those accessible in the distance modality with a metaverse-based environment. That is, what theories can be observed with this practice? What is the impact on the teaching-learning process? Which indicators (school performance, evasion, motivation) recognized in the pedagogical evaluation instruments can this initiative impact? In addition, investigating the sense of presence in the metaverse can impact different aspects, such as academic performance, student dropout rates, the interaction between students and teachers, and its measurement and evaluation methods.

The alignment between the associated technologies and a pedagogical study can be a guideline for the survey and alignment of technical and functional requirements. For example, what should the platform provide? Parallel to this alignment, it is vital to brainstorm between research, design, pedagogical, and infrastructure teams to identify the main points related to meeting the needs of users who will have the EaD platform. From this, identify the requirements to be designed in the prototype and from the system's end users to obtain information about the application domain, the services the system must offer, the system performance, hardware restrictions, and so on. As an open challenge, there are development options such as virtual room, chat, interactive whiteboard, voice conversation, screen sharing, and avatar customization, considering accessibility for different types of profiles, such as visually impaired, hearing impaired, and low vision.

5.3. Adapting associated technologies

Studies have highlighted e-learning platforms like Moodle, Second Life, and 3DVWs, which provide virtual student interaction and collaboration environments. These platforms are complemented by Mozilla Hubs, Autodesk Revit, and SimLab GLTF exporter

[2]https://github.com/Aca1990/VoRtex-School

tools for communication and content creation within the metaverse. Virtual reality (VR) features, including Google Cardboard VR viewers and the magic window setup, enhance the immersive learning environment by enabling VR visualization using smartphones without needing a headset. Moreover, VR headsets like Oculus Quest and HMDs are utilized for visualization and interaction in the virtual educational environment, supporting software applications like BananaVision and BanAnatomy.

However, there is still a gap in research on adapting these tools for people with disabilities in distance learning. In face-to-face education, the entire technological infrastructure must be ensured. However, the question arises regarding how to provide adapted devices and adequately guide students in distance learning. Additionally, how can we ensure a sense of presence through the use of these tools? Among the investigated works, Qorbani et al. (2022) explored how to facilitate vertical movement in an RV environment for wheelchair users. Such adaptations can be crucial in enabling students with disabilities to have immersive experiences, positively impacting their learning.

Different technologies applied in the various layers of the metaverse must be considered in addition to "wearable" devices. This includes DDBMS and NoSQL databases and access control features such as biometrics, facial/voice recognition, and the use of virtual worlds, intelligent agents, digital avatars, and 3D assets. In this sense, it is important to question whether the stakeholders (designers, developers, among others) of projects related to this theme have applied the appropriate technologies to cover all people. We emphasize that it is essential to adapt education and metaverse systems, such as simply implementing an accessibility toolbar and specific education and metaverse projects with wearable devices or support equipment adapted for PwD (such as wheelchairs). An additional consideration is that some studies have not adequately addressed the concept of "a *massive virtual environment parallel* to the physical world" [Lee et al. 2021], which is frequently used to define the Metaverse. With the exception of Brown et al. (2023), most proposals do not explicitly state whether their approach supports interaction among multiple users making the challenges more complex when ensuring adequate accessibility in a massive educational environment.

6. Conclusions

This paper explores the interaction between the metaverse, assistive technologies, and distance education. The research objective was to gather, organize, and analyze state-of-the-art evidence through a Rapid Review. Although we found a limited number of studies explicitly addressing accessibility in the metaverse, these studies emphasized the need for solutions to ensure that PwD can access and fully participate in these virtual environments. The challenges associated with implementing accessibility in the metaverse include adapting interfaces for different disabilities, the availability of compatible assistive technologies, and raising developers' awareness of the specific needs of PwD. These findings aim to encourage further research and development of inclusive and accessible educational solutions in the metaverse, promoting equal opportunities and rights for all. Future work involves expanding the study to a Multivocal Literature Review, proposing solutions for the involved company, and exploring insights from traditional distance education and metaverse-based approaches.

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