

The Impact of Immersive Technologies on Learning and Inclusion of Students with Sensory Disabilities: Pedagogical Perspectives and Practical Challenges

Generoso Romano

University of Naples "Parthenope"
generoso.romano@uniparthenope.it

Francesco Tafuri

University of Campania "L. Vanvitelli"
francesco.tafuri@unicampania.it

Abstract

The integration of immersive technologies such as virtual reality (VR) and augmented reality (AR) into educational settings has opened new avenues for enhancing learning experiences, particularly for students with sensory disabilities. These technologies offer unique opportunities to create multisensory, interactive environments that can overcome traditional barriers to access and participation. This literature review critically examines the pedagogical potential of VR and AR to support inclusive education by facilitating personalized learning, fostering engagement, and promoting autonomy among learners with hearing or visual impairments. While evidence indicates significant benefits in motivation, comprehension, and social inclusion, the implementation of immersive technologies also presents challenges including high costs, technological limitations, and the need for specialized teacher training. The review further discusses how the design and deployment of these tools must consider accessibility principles and the diverse needs of sensory-impaired students to avoid exacerbating existing educational inequalities. Finally, this article outlines future research directions and policy recommendations aimed at optimizing the use of immersive technologies to create equitable and effective learning environments for all students. This study contributes to the growing field of technology-enhanced inclusive education by offering a comprehensive analysis of current practices and identifying critical areas for development and innovation.

Key words: Immersive Technologies, Virtual Reality, Augmented Reality, Sensory Disabilities, Inclusive Education, Pedagogical Innovation.

Introduction

The rapid advancement of immersive technologies, particularly virtual reality (VR) and augmented reality (AR) has opened unprecedented avenues for transforming educational practices, especially within inclusive settings where diverse learners require tailored pedagogical approaches. The integration of these technologies into education has sparked considerable interest due to their potential to create multisensory, interactive, and engaging learning environments that extend beyond the limitations of conventional classrooms. This potential is especially significant when considering students with sensory disabilities, who often face unique barriers to learning in mainstream educational contexts. Sensory disabilities such as deafness or blindness pose particular challenges in accessing information predominantly delivered through auditory or visual channels. Consequently, the traditional educational landscape frequently falls short in providing equitable learning opportunities for these students. The employment of immersive technologies offers an innovative solution by

enabling alternative modes of content delivery that can be customized to meet individual sensory and cognitive profiles, thereby enhancing accessibility and promoting active participation (Radianti, Majchrzak, Fromm, & Wohlgenannt, 2020).

The importance of inclusive education has been firmly established within international frameworks, most notably the United Nations Convention on the Rights of Persons with Disabilities (UNCRPD, 2006), which explicitly underscores the right of persons with disabilities to access education on an equal basis with others. This global mandate reflects a paradigm shift away from segregated special education toward models that embrace diversity and foster the full participation of all learners in regular educational settings. Nonetheless, despite growing policy commitments to inclusion, practical implementation remains fraught with challenges. Students with sensory disabilities continue to encounter physical, communicative, and attitudinal barriers that impede their educational progress. It is in this context that immersive technologies emerge not only as assistive tools but as catalysts for redefining the boundaries of learning environments and pedagogical practices (Freina & Ott, 2015).

Virtual and augmented reality provide immersive experiences that simulate real-world or imagined scenarios through multisensory input, including visual, auditory, and haptic feedback, thus accommodating learners who rely on alternative sensory channels. For example, VR environments can be designed to emphasize tactile and spatial cues, supporting learners with visual impairments, while AR applications can overlay visual sign language prompts or captions to aid deaf students in following instructional content. Such technologies facilitate experiential learning by situating learners within dynamic contexts where abstract concepts become tangible and where interaction is immersive rather than passive. This can significantly improve cognitive engagement, motivation, and retention, which are crucial for students who may otherwise struggle with traditional didactic approaches (Bacca, Baldiris, Fabregat, Graf, & Kinshuk, 2014). Moreover, the ability to customize immersive experiences enables educators to differentiate instruction and address individual learning preferences and abilities in ways that were previously unattainable, contributing to more personalized and effective teaching.

Despite these promising possibilities, the integration of immersive technologies in education for sensory-disabled learners is not without limitations and complexities. One key concern pertains to equitable access, as disparities in socioeconomic status, geographic location, and institutional resources may restrict the availability of VR and AR tools to certain populations, thereby risking the exacerbation of existing educational inequalities (McMahon, Cihak, & Wright, 2019). Additionally, the rapid pace of technological innovation often outstrips the capacity of educational institutions to provide adequate infrastructure, technical support, and professional development for teachers, which are essential for effective implementation. Without comprehensive training and ongoing support, educators may lack the confidence or competence to integrate immersive technologies meaningfully into their pedagogical practices, undermining their potential benefits (Lau & Lee, 2020). Furthermore, there are pedagogical considerations regarding how best to align immersive technology use with curricular goals, assessment standards, and developmental appropriateness for learners with sensory disabilities.

Ethical and accessibility issues also warrant critical attention. For instance, the sensory stimuli within immersive environments must be carefully designed to avoid causing discomfort or cognitive overload, particularly for students with sensory processing differences or additional disabilities. Privacy concerns arise as immersive systems increasingly collect and analyze learner data to personalize experiences, raising questions about consent and data security. Furthermore, the promotion of technology should not overshadow the fundamental importance of human interaction, culturally responsive teaching, and community involvement,

all of which remain vital components of inclusive education for sensory-disabled students (Dede, 2016).

Research on the efficacy of immersive technologies in special education contexts is still emerging but growing rapidly. Studies indicate that VR and AR can enhance spatial awareness, language development, and social skills among learners with sensory disabilities, while also supporting skill acquisition in subjects such as mathematics, science, and literacy (Sutherland, McQuillan, & Webb, 2021). Nonetheless, much of the research to date has been limited by small sample sizes, short intervention durations, or lack of control groups, pointing to the need for more rigorous, longitudinal studies to validate and refine best practices. Additionally, there is a growing recognition of the importance of involving sensory-disabled individuals and their families in the design and evaluation of immersive educational technologies to ensure that these tools truly meet their needs and preferences (Kelly et al., 2020).

This paper aims to synthesize current knowledge concerning the use of immersive technologies for sensory-disabled learners within inclusive education frameworks, exploring both theoretical underpinnings and empirical evidence. It will critically examine the pedagogical affordances and challenges associated with VR and AR, considering technological, social, and ethical dimensions. The discussion will address key issues including accessibility and equity, educator training and readiness, learner engagement and outcomes, as well as the broader implications for educational policy and practice. By providing an integrative overview, this research seeks to inform stakeholders, including educators, researchers, policymakers, and technology developers, about the opportunities and responsibilities inherent in leveraging immersive technologies to support the academic and social inclusion of sensory-disabled students. Ultimately, the goal is to advance an inclusive educational paradigm where technology acts not merely as an add-on, but as an integral element of a learner-centered, culturally sensitive, and equitable system that empowers all students to achieve their full potential.

1. Immersive Technologies: Definition and Potential

Immersive technologies represent a groundbreaking category of digital tools designed to create engaging and interactive perceptual experiences that expand traditional modes of learning and communication. Among these, virtual reality (VR) and augmented reality (AR) play a central role due to their ability to transform educational environments into dynamic, multisensory spaces. Virtual reality is defined as a computer-generated simulated environment that fully immerses the user in a three-dimensional setting, typically accessed through devices such as headsets and headphones that isolate the experience from the real world. This complete immersion allows students to interact with virtual content in ways that replicate or extend physical reality, facilitating complex cognitive processes and skill acquisition through direct experience (Slater & Sanchez-Vives, 2016). Augmented reality, in contrast, overlays digital elements onto real-world scenes using mobile devices, smart glasses, or tablets, enriching the surrounding environment with additional visual, auditory, or tactile information without detaching the user from the physical context. This feature makes AR particularly effective in integrating educational supports within everyday settings and promoting a more seamless and contextualized engagement with learning materials (Azuma, 1997).

The distinctive qualities of immersive technologies lie in their capacity to provide multisensory input, engaging not only sight and hearing but also touch and proprioception, essential components for constructing rich and complex mental representations. These features prove especially valuable in inclusive education settings, where students with sensory disabilities often face significant limitations in receiving and processing information. For instance, students with visual impairments can benefit from VR experiences designed to emphasize tactile and auditory cues, enabling them to explore virtual environments through

vibrotactile feedback and spatialized sounds. Similarly, deaf or hard-of-hearing students can be supported by augmented reality applications that display real-time text, dynamic signage, or even sign language avatars integrated into live lessons (Bailenson, 2018).

In education, the application of VR and AR manifests in various ways. Virtual reality is employed for scientific simulations, historical reconstructions, and immersive experiences that allow students to manipulate complex objects and engage in situations that are difficult to replicate in traditional classrooms. This opportunity fosters active learning and the development of transversal skills such as problem-solving and collaboration, which are particularly relevant for students with special educational needs (Freina & Ott, 2015). Augmented reality, on the other hand, has been effectively applied in overlaying real-time educational information, supporting reading and spatial orientation, contributing to reducing learning barriers and promoting greater autonomy among students with sensory disabilities (Cheng & Tsai, 2019).

The potential benefits of immersive technologies extend beyond merely facilitating content access. They include increased motivation and engagement stemming from the interactive and playful nature of these technologies, which is especially important for students with disabilities who often face frustrating or exclusionary educational experiences. Moreover, immersive technologies allow for personalized learning that caters to the sensory and cognitive specificities of each individual by adapting content, pacing, and modes of interaction. This capacity for customization is supported by a growing body of research demonstrating that personalization can improve both cognitive and affective outcomes, reinforcing self-esteem and social participation (Radianti, Majchrzak, Fromm, & Wohlgenannt, 2020).

Another significant advantage of immersive technologies is their ability to simulate real-life or social learning situations, fostering the development of socio-emotional and communication skills. For students with sensory disabilities, this aspect is crucial, as they often encounter challenges in social interaction and acquiring alternative communicative codes. Through virtual environments, it is possible to recreate interaction scenarios, sign language exercises, or collaborative activities that facilitate contextualized learning and social inclusion (Lindgren & Johnson-Glenberg, 2013).

Despite these evident potentials, it is important to emphasize that the effectiveness of VR and AR in educational contexts depends on pedagogically sound usage and inclusive design that considers the specific characteristics of students with sensory disabilities. The mere adoption of technology without appropriate instructional strategies risks transforming these innovations into superficial or exclusionary tools that fail to overcome existing barriers. Therefore, teacher training and multidisciplinary collaboration among educators, technologists, therapists, and families represent key factors for the effective and sustainable integration of immersive technologies into inclusive pedagogy (Bower, Howe, McCredie, Robinson, & Grover, 2017).

Immersive technologies such as virtual reality and augmented reality offer a broad range of opportunities to revolutionize inclusive learning, especially for students with sensory disabilities. Their ability to create multisensory, personalized, and interactive environments represents an important resource to overcome the limitations of traditional methodologies, promoting not only knowledge acquisition but also socio-emotional skills and autonomy development. To fully realize these potentials, an integrated approach is necessary, valuing ongoing teacher education, student-centered pedagogical design, and collaboration among diverse educational stakeholders. Only through such means can immersive technologies effectively contribute to making schools truly inclusive spaces capable of responding to the diverse needs of all learners.

2. Pedagogical and Didactic Approaches with Immersive Technologies

The integration of immersive technologies such as virtual reality (VR) and augmented reality (AR) into educational practices demands innovative pedagogical strategies that capitalize on their unique affordances to foster active, multisensory, and personalized learning experiences. Contemporary research underscores the importance of moving beyond traditional didactic methods towards models that promote learner engagement, autonomy, and meaningful interaction within immersive environments (Radianti et al., 2020). Active learning approaches within VR and AR contexts encourage students to manipulate virtual objects, explore scenarios, and engage in problem-solving tasks that deepen cognitive processing and conceptual understanding. This active engagement contrasts with passive content delivery and is especially beneficial for students with diverse sensory and cognitive profiles, as it facilitates differentiated instruction tailored to individual needs and strengths (Freina & Ott, 2015).

Multisensory learning models enabled by immersive technologies engage visual, auditory, and tactile senses simultaneously, fostering richer mental representations and supporting learners with sensory disabilities. For example, AR applications that incorporate visual cues, auditory feedback, and haptic responses provide scaffolds that enhance comprehension and retention. This approach aligns with theories of embodied cognition which posit that learning is deeply rooted in sensorimotor experiences and bodily interactions with the environment (Lindgren & Johnson-Glenberg, 2013). Such embodied learning experiences within immersive environments support not only academic skills but also social communication competencies by simulating interactive, real-world contexts where students can practice language and social behaviors in a safe, adaptive setting.

Personalization constitutes a core element of effective didactic strategies with immersive technologies. VR and AR platforms can be designed to adapt to learners' pace, modality preferences, and performance, providing individualized scaffolding and feedback. For deaf students, this may include visual and sign language supports integrated within virtual lessons, while for students with visual impairments, spatial audio and tactile elements can be emphasized. The flexibility of immersive environments thus supports inclusion by accommodating a spectrum of abilities and learning preferences, facilitating equitable access to curriculum content and promoting learner confidence and motivation (Bailenson, 2018).

Immersive technologies also offer unique affordances for enhancing communication and social interaction in educational settings. VR platforms can create collaborative virtual spaces where students interact via avatars or video-mediated sign language, facilitating peer learning and social inclusion. AR applications can augment real-time communication by providing captioning, translation, or sign language interpretation embedded directly into the learner's physical environment. These communicative supports are critical for deaf and hard-of-hearing students, for whom social isolation and communication barriers often impede academic and emotional development (Napier & Leeson, 2016). By enabling accessible and contextually relevant social experiences, immersive technologies contribute to the cultivation of inclusive classroom cultures and peer relationships.

However, the successful implementation of immersive pedagogies requires intentional instructional design informed by research on effective teaching and learning. Educators must develop competencies in both technological fluency and inclusive pedagogy to harness the full potential of VR and AR. Professional development and collaborative design processes involving educators, technologists, and users with disabilities are vital to creating immersive learning experiences that are pedagogically sound and culturally responsive (Bower et al., 2017). Moreover, ethical considerations regarding data privacy, equity of access, and potential sensory overload must be addressed to ensure these technologies serve all learners fairly and safely.

Pedagogical and didactic approaches that integrate immersive technologies like VR and AR offer promising pathways for creating active, multisensory, personalized, and socially inclusive learning environments. When combined with teacher expertise and inclusive design principles, these technologies can transform educational experiences, particularly for students with sensory disabilities, by overcoming traditional barriers and fostering holistic development.

3. Impacts on School Inclusion and Learning

Immersive technologies such as virtual reality (VR) and augmented reality (AR) have increasingly become a focal point in research exploring their effects on inclusion and learning outcomes for students with sensory disabilities, offering promising evidence of their capacity to enhance accessibility, motivation, autonomy, and academic success within educational settings. Empirical studies have shown that these technologies provide multi-modal sensory inputs that can be tailored to individual learning profiles, thereby addressing longstanding barriers that students with hearing or visual impairments often face in traditional classroom environments (Bailenson, 2018). For instance, VR's ability to simulate environments that amplify or substitute sensory information allows learners with visual impairments to engage spatial and auditory cues more effectively, thus enhancing comprehension and orientation skills (Lahav & Mioduser, 2008). Likewise, AR applications provide real-time visual and textual supports that facilitate communication and understanding for deaf students by integrating sign language, captions, or symbolic representations directly within the physical learning environment (D'Cruz et al., 2020). Such augmentation of sensory input not only makes curriculum content more accessible but also cultivates a more equitable learning experience where students with disabilities can participate meaningfully alongside their peers.

In terms of motivation, immersive environments have demonstrated significant capacity to engage learners by offering interactive, gamified, and contextually rich experiences that foster intrinsic interest and sustained attention (Radianti et al., 2020). For students with sensory disabilities, who may encounter social isolation or frustration within traditional pedagogies, VR and AR provide inclusive platforms where learning is both immersive and enjoyable, which can lead to improved attendance, participation, and perseverance in academic tasks (Merchant et al., 2014). These technologies enable learners to exercise agency by controlling the pace and pathways of their interactions, which promotes autonomy and self-directed learning. This sense of control is particularly important for deaf students, as studies have highlighted the challenges related to communication barriers and social inclusion that can undermine motivation and academic engagement (Napier et al., 2010). By fostering environments that adapt to their communication preferences and sensory needs, immersive technologies contribute to a positive educational identity and encourage students to take active ownership of their learning journeys.

Autonomy in learning, supported by immersive technologies, also intersects with the development of executive functioning skills such as problem-solving, planning, and self-regulation, which are critical for academic success across disciplines (Shute & Ventura, 2013). VR simulations often require learners to navigate complex tasks that necessitate critical thinking and decision-making, skills that are transferable beyond the virtual context into real-world academic challenges (Dede, 2009). Furthermore, the adaptive nature of AR systems enables scaffolding that is responsive to learners' evolving abilities, offering just-in-time support that scaffolds independence rather than dependence on adult mediation (Billinghurst & Duenser, 2012). For students with sensory impairments, whose access to incidental learning and informal social interactions may be limited, these technologies provide alternative pathways for practicing cognitive and social skills within safe, scaffolded virtual spaces (Kirk et al., 2020).

Academic achievement among students with sensory disabilities has shown positive correlations with the integration of immersive technologies when these are embedded within

comprehensive pedagogical frameworks. Research indicates that immersive environments can facilitate mastery of complex content by providing concrete, experiential learning opportunities that bypass the limitations of text- or speech-dependent instruction (Bower et al., 2017). For deaf students, who may experience delays in language acquisition and literacy development due to limited access to spoken language input, AR and VR can support bilingual education models by visually reinforcing language concepts through immersive and interactive modalities (Swanwick & Marschark, 2010). This multimodal reinforcement supports vocabulary acquisition, reading comprehension, and conceptual understanding, which are foundational for academic progress. Similarly, students with visual impairments benefit from spatialized audio and haptic feedback within VR environments that provide alternative sensory routes to content comprehension and participation (Lahav & Mioduser, 2008). These approaches contribute to closing achievement gaps and supporting inclusive academic outcomes.

Despite the evident benefits, it is crucial to emphasize that the positive impacts of immersive technologies on inclusion and learning depend on their thoughtful integration within inclusive educational policies, teacher training, and ongoing technical support (Bower et al., 2017). Studies have consistently highlighted the necessity for educators to develop digital literacy and inclusive pedagogical competencies to leverage the full potential of VR and AR tools effectively (Huang et al., 2020). Moreover, the infrastructure and equitable access to these technologies remain significant factors influencing their efficacy, as disparities in availability and support can exacerbate existing educational inequities (Soto et al., 2021). Therefore, systemic commitment to resource allocation, professional development, and inclusive curriculum design is essential to realize the transformative promise of immersive technologies.

Empirical evidence affirms that immersive technologies contribute substantially to improving school inclusion and learning outcomes for students with sensory disabilities by enhancing accessibility, increasing motivation, fostering autonomy, and supporting academic achievement. These technologies enable multisensory, personalized, and socially interactive learning experiences that bridge communication and sensory barriers, promoting equitable participation in educational environments. To maximize their benefits, sustained investment in inclusive pedagogical frameworks, educator training, and infrastructure equity is imperative. Continued research is necessary to refine best practices and ensure that immersive technologies fulfill their potential as tools for educational inclusion and empowerment.

Conclusions

The integration of immersive technologies such as virtual reality and augmented reality within educational settings for students with sensory disabilities represents a transformative opportunity to advance inclusive education and enhance learning outcomes. The empirical evidence indicates that these technologies significantly improve accessibility by offering multisensory and customizable experiences that accommodate diverse learning needs. Furthermore, immersive environments foster greater student motivation and engagement by providing interactive, meaningful, and contextually rich learning experiences that support autonomy and self-directed learning. These factors collectively contribute to narrowing achievement gaps by enabling learners with sensory impairments to access curricular content in innovative ways that transcend the limitations of conventional pedagogical approaches. However, the realization of these benefits depends on thoughtful implementation embedded within inclusive educational frameworks, requiring ongoing professional development for educators and equitable access to technology. Addressing infrastructural disparities and fostering a supportive ecosystem that integrates technology with pedagogy and policy is essential for sustainable impact. Future research and practice should continue to explore how immersive technologies can be optimized to meet the evolving needs of students with sensory

disabilities and contribute to educational equity, inclusion, and empowerment on a broader scale.

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