ARTIFICIAL INTELLIGENCE AND VIRTUAL LEARNING ENVIRONMENTS: LIMITS AND OPPORTUNITIES FOR BLIND STUDENTS

INTELLIGENZA ARTIFICIALE E AMBIENTI DI APPRENDIMENTO VIRTUALI: LIMITI E OPPORTUNITÀ PER GLI STUDENTI CON DISABILITÀ VISIVA

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ABSTRACT
Metaverse represents a further evolutionary stage of the ongoing educational digital transformation which leads to a redefinition of the concepts of body, environment, perception and interaction. Considering that the learning process of blind students is deeply affected by the non-visual perception of the environment, it is necessary to reflect on how digital barriers can be overcome by allowing blind students to access the virtual learning environment thus promoting a real inclusive education.

Il metaverso rappresenta un'ulteriore fase evolutiva dell'attuale processo di trasformazione digitale dell'educazione che implica una ridefinizione dei concetti di corpo, ambiente, percezione ed interazione. Considerato che il processo di apprendimento degli studenti con disabilità visiva è profondamente condizionato dalla percezione non visiva dell'ambiente, è necessario riflettere sulle modalità di superamento delle barriere digitali per consentire loro di accedere agli ambienti di apprendimento virtuali al fine di promuovere un'educazione realmente inclusiva.

KEYWORDS
Visual disability, inclusive digital education, e-accessibility, Embodied Cognition.
Disabilità visiva, educazione digitale inclusiva, accessibilità digitale, Embodied Cognition.

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Introduction

Metaverse and Artificial Intelligence are considered the new evolution of the Internet. They are becoming an integral part of people's everyday lives, extending to all spheres of life, including education. These digital products are transforming the web by generating new forms of virtual reality that tend to blur the boundary with physical reality and define new hybrid dimensions of being. This implies a redefinition of certain fundamental concepts, including those of environment and perception. Perception plays a fundamental role in man's contact with the outside world. It participates in the determination of the environment, defining it as a space of personal meaning. Therefore, for virtual reality to be meaningful, it must be perceived (Di Tore & Sibilio, 2022).

Perception is the point of contact between an individual and his surroundings and is essential for the process of cognition. This mix plays a fundamental role in the teaching-learning process. However, it is important to note that it is not just individual perception that leaves a trace of an experience, but rather the perceptual mix produced by the different stimuli that the body receives contextually (Sibilio, 2020).

New technologies can recreate certain types of perception. However, they cannot recreate them all at the same time. This is one of their current limitations, which is even more increased in the case of people with visual impairments. For a person with typical development, the contextual occurrence of multiple perceptions is fundamental for activating the cognitive process and leaving a meaningful trace of an experience. This is even more important for a person with visual impairment. In this case, the absence of sight is compensated for by the enhanced development of the other senses. These senses perform a vicarious function, allowing for the creation of original and valid adaptive solutions.

There is no doubt about the potential of new technologies to improve digital education. However, the current challenge for education is to create digital learning environments that offer meaningful learning experiences. In order to achieve this, digital learning environments need to be responsive to the needs of all learners, including those with visual impairments.

Based on these premises, this paper aims to analyse the limits and opportunities of digital educational environments for visually impaired learners, in order to highlight possible critical issues related to the accessibility of these places.

1. The digital transformation of educational environments

In the context of Mission 4 – *Education and Research, Component 1 – Strengthening the supply of education services from kindergartens to universities*, included within the National Recovery and Resilience Plan (PNRR), the Italian Ministry of Education has proposed the establishment of an investment line, designated as 'School 4.0', with an estimated budget of EUR 2.1 billion. This initiative is intended to facilitate the improvement and innovation of learning environments. This measure is in continuity with other previous initiatives, including the National Plan for the Digital School (PNSD) drawn up in 2015 and subsequently the European funds aimed at increasing research and training in the digital sphere (*Digital Europe* 2021-2027). These have been driving the process of digitisation of Italian teaching and school organisation for approximately fifteen years. These measures are consistent with the OECD's (Organisation for Economic Co-operation and Development) affirmation of the characteristics of optimal physical learning environments, which must be adequate, efficient, and effective (2017). Additionally, they align with UNESCO's conceptualisation of the "intelligent learning environment" and the Council of Europe's stance on creating safe, inclusive, and effective learning environments for all (European Schoolnet, 2019). Furthermore, they align with Goal 4 of Agenda 2030 – "Provide quality, equitable and inclusive education and learning opportunities for all" (UNESCO, 2019).

In essence, the aspiration to transform learning environments can be attributed to the necessity to align them with the evolving needs of contemporary students, who have different characteristics from those of their predecessors. Consequently, traditional learning environments, which remain pervasive despite concerted efforts at the international level to foster innovation, are unable to adequately address the needs of modern students.

Indeed, since the latter decades of the previous century, the educational scientific community has demonstrated a notable enthusiasm for the integration of technology in traditional learning environments. This has manifested in the initial phase of digitisation of learning environments, which is commonly referred to as Technology-Enhanced Learning (TEL). However, the limitation of the current situation lies precisely in the fact that this phase has not yet been completely overcome. Consequently, technology is still too often used to supplement rather than guide the learning environment. In light of this, UNESCO has identified the necessity for the design of Smart Learning Environment (SLE) in its 2017 document. This is defined as “an adaptive system that puts the learner at the forefront;

improves learning experiences for the learner based on learning traits, preferences and progress; features increased degrees of engagement, knowledge access, feedback and guidance; and uses rich-media with a seamless access to pertinent information, real-life and on-the-go mentoring, with high use of AI, neural networks and smart-technologies to continuously enhance the learning environment" (UNESCO, 2017, p. 9).

The 'School 4.0' strategy, adopted by Ministerial Decree No. 161 of 14 June 2022, is a document that outlines the process of transforming classrooms into smart learning environments. This transformation encompasses both physical and digital spaces. In the first case, it is necessary to select furniture that is mobile, as this allows for greater flexibility in adapting spaces to the different teaching methodologies used by teachers. In the second case, it is necessary to update the teaching environment to adapt it to the digital era. This can be achieved by implementing the development of technologies such as *eduverso*, e-learning and the use of immersive reality to recreate the classroom in the virtual environment. The result is the construction of a hybrid learning environment, in which the boundary between real and virtual becomes increasingly indistinct, creating an educational and scholastic continuum between physical and virtual space for learning, that is to say, an *on-life learning environment* (School Plan 4.0).

In accordance with an ecosystem approach, given the inherent complexity of the educational environment and the profound value it represents for learning, the design of the transformation of existing spaces into innovative environments promoted by this investment strategy, as well as covering various aspects, involves the entire school community. In fact, the design of the learning environments is entrusted to a design group coordinated by the school head, which includes the digital animator, the innovation team and other instrumental figures, teachers and students. Furthermore, the digitisation process must not neglect the innovation of the pedagogical core, which encompasses the promotion of innovative pedagogies and related teaching methodologies. Finally, the necessity for continuous teacher training, which aims to enhance the role of the teacher as a "creative professional of the learning process" (Id.), is also oriented towards the development of digital competences in accordance with the indications of the European reference framework *DigCompEdu*.

2. The relationship between body and perception in the context of reality technologies.

The digitisation process, which began approximately fifty years ago, has increasingly evolved, gradually involving all areas of everyday life. Initially, the first phase of Internet evolution, designated Web 1.0, was based on indirect communication principles and was primarily accessible to an audience of expert users. Subsequently, it proceeded to a second phase, designated Web 2.0, which was based on the principles of direct interaction, sharing, and active participation of the ordinary user. This phase completely revolutionised the way people communicate. However, both of these phases can be defined as belonging to the period of the so-called *mobile Internet* insofar as access to the Internet is conditional on the use of one or more technological devices for which the subject chooses the ways and times in which to be interconnected. Conversely, the current phase is distinguished by a growing prevalence of immersive reality, which has identified the metaverse as one of its most pioneering applications.

> "The advent of *mobile internet* led to a significant shift in global consumer behaviour, with a vast majority of individuals purchasing their own personal computer and internet service. This resulted in a universal access to computing and connectivity. The metaverse builds upon this concept by placing everyone within an 'embedded', 'virtual' or '3D' version of the internet, with an almost infinite degree of connectivity. In other words, the user is not merely accessing the internet, but rather is situated within it. This is not simply a matter of occasional reachability, but rather a continuous immersion within the billions of interconnected computers that comprise the internet" (Accoto, 2022, p. 116).

In this context, the metaverse can be defined as an evolutionary stage subsequent to the mobile internet (Di Tore & Sibilio, 2022). During an interview, Mark Zuckerberg, the founder of Meta, one of the leading international companies in the development of this new technology, defines the metaverse as "an 'embodied internet' operated by many different players in a decentralized way" (https://www.theverge.com/22588022/mark-zuckerberg-facebook-ceo-metaverse-interview).

The term 'eduverse' has been coined to describe the application of the metaverse in education. The development of this technology is contingent upon the advancement of virtual reality (VR), which has been the subject of investigation in various educational contexts since the late 1990s. The objective of the school digitisation process is to create smart learning environments that facilitate the development of meaningful learning experiences in immersive reality contexts.

In accordance with the definition provided by Gros, “smart learning is founded on two different types of technology: smart devices and intelligent technologies. Smart devices refer to artefacts that exhibit some properties of ubiquitous computing, including (although not necessarily) artificial intelligence; for instance, the Internet of things, wearable technology in the form of an accessory such as glasses, a backpack, or even clothing” (Gros, 2016, p. 3). Intelligent technologies refer to learning analytics, cloud computing and AI capabilities, and are vital in capturing valuable learning data that can effectively enhance the development of personalized and adaptive learning (Mayer et al., 2013; Picciano, 2012). In order for virtual reality to produce an immersive experience, it is necessary for certain devices to be in place that are capable of reproducing sensory perceptions. These devices include head-mounted displays (HMDs) or goggles for the reproduction of visual stimulation, headphones for the reproduction of auditory stimulation, and data gloves for the reproduction of tactile stimulation. In fact, an environment is considered immersive to the extent that it is able to deceive a person's cognitive and perceptual system into believing they are in a different place than they physically are (Patrick et al., 2000). However, in order to guarantee the learner's involvement and interactivity within the immersive reality, the mere reproduction of perceptual stimuli is not sufficient; it is necessary for the learner to have the subjective perception of being psychologically present and acting within a learning space. Therefore, the concepts of *presence* and *agency* are closely linked to the degree of involvement and level of interactivity experienced by the learner (Finestrone et al., 2023). Furthermore, in addition to the components of presence and agency, the implications of cognitive skills, motivation and emotional participation, which influence the internalisation of knowledge and the academic performance of students, are fundamental (Dangel & Mägdefrau, 2020). Therefore, the educational challenge of our times concerns the possibility of making this mediation system increasingly embodied and interactive.

The principal distinguishing feature of this embodied Internet is its marked divergence from the preceding evolutionary phases of the Internet. This divergence is characterised by the increasing invisibility of technology and the emergence of more immersive forms of engagement. The reconfiguration of the digital environment is no longer limited to recreational purposes (such as video games) or social networking. Instead, it is intended to act as an 'extension' of the spaces of everyday life, including educational venues. "VR, AR, XR, metaverse, artificial intelligence and the Internet of Things are set to become technologies of reality that shape and create new realities at a deeper and more complex level than ever before" (Di Tore & Sibilio, 2022, p.14).

In this context, it can be argued that these technologies necessitate a redefinition of the concept of reality. The latter, understood as *Umwelt*, that is, as a space of signification derived from personal perception (Kull, 2001), becomes *Metawelt*, that is:

> "a modular, extensible, augmented *Umwelt*, an interface to which it is possible to connect 'new pieces of the world' – Weltstuck – (media, web, metaverse), which immediately inherit the semantic processes of departure, and immediately redefine them by returning them to the original *Umwelt* in a non-linear process. The concept of the 'new pieces of the world' (Weltstuck) – which includes media, the web and the metaverse – is one that immediately inherits the semantic processes of departure and is then re-defined by returning them to the original Umwelt in a non-linear process. The least common denominator of all possible milleplanes is, and remains, the inter-acting subject" (Sibilio, 2020; Di Tore & Sibilio, 2022, p. 24).

In this sense, intelligent learning environments are spaces in which the use of innovative technologies and elements allow greater flexibility, adaptation, engagement, and feedback for the learner (Spector, 2014). All in all, these technological advancements are potentially revolutionary for the way teachers and learners interact, paving the way for more learner-centred learning environments (UNESCO, 2017).

3. The accessibility of visually impaired students to digital learning environments.

The centrality assumed by the body in cognitive processes represents the main idea of the *Embodied Cognition* paradigm, which began to assert itself from the last decade of the last century (Caruana & Borghi, 2016). This assertion was also made possible by the important contribution made by neuroscience. Indeed, the outcome of research carried out in this scientific field has demonstrated the existence of relations between cognitive functions and the sensorimotor system, such that we can speak of embodied cognition. This approach represented a departure from classical cognitivism, which had its roots in modern philosophy and was based on the mind-body dichotomy, understood in a relationship of subordination of the latter to the former. It had gained significant traction between the 1950s and 1980s and was based on the fundamental concepts of mental representation and computational processing (Id.).

The *Embodied* perspective has been widely endorsed internationally, giving rise to a variety of study orientations. In particular, the phenomenological approach posited that perception should be accorded greater priority than action, with the sensory component being given greater weight than the motor component. This philosophical stance was justified by the emphasis placed by Husserl and Merleau-Ponty on the value of perception. Another theoretical current was represented by what is known as American pragmatism, which, in contrast, upheld the priority of action over perception. Other relevant strands of study include Gilbert Ryle's logical behaviourism and Gibson's ecological psychology (Id.).

Despite the existence of a multitude of orientations, in Europe the phenomenological current has prevailed, whereas the focus on the motor aspect is derived from the ecological approach. Indeed, a fundamental concept at the core of the *Embodied* paradigm is that of *affordance*, first introduced by the American psychologist Gibson in the mid-1960s when he developed his theory of perception. However, this concept has not been fully embraced by the cognitive sciences due to the dominance of the cognitivist orientation. The theory of *affordance*, as developed by Gibson, posits that perception is the ability to extract information from the environment that is necessary for action. This information is not mediated by mental representations and is therefore direct.

Through perception, understood as the individual's ability to select the *affordances* necessary to meet their needs, the individual can thus define their *Umwelt*, i.e. the perceptual space that is meaningful to them.

> "The phenomenal world is organised and perceived by organisms with specific biological configurations. These organisms act on the basis of their own *monde vécu* in an adaptive logic aimed at ensuring the survival of the species. This logic is based on the simplification of perceptual stimuli from the external environment, which enables the selection of the information necessary to act" (Sibilio et al., 2017, p. 219).

It can therefore be argued that corporeality represents the element that defines cognition, and perception is the instrument through which the body makes contact with external reality in order to act and be acted upon by it. This process of interaction is defined by the enactive perspective (Varela et al., 2017), whereby man and environment co-evolve and co-specify. Consequently, perception represents not only the means by which humans interact with their environment but also the means by which they create their own space. As Merleau-Ponty (1976) asserts, *space exists only when perceived*. Therefore, space is a *potentiality* insofar as it represents *the possible location of our actions* (Humeau, 2004; Sibilio et al. 2017).

In the field of education, didactics can be defined as the body of knowledge pertaining to the teaching-learning process. This process is shaped by the adaptation of the educator to stimuli from the environment, and pursues different objectives (educational, formative, inclusive, etc.) depending on the form it takes (Sibilio et al., 2017). From this consideration, it can be seen that the educational setting is of great importance, as perception plays a central role in the cognitive process, whether it takes place in a physical environment or develops in the virtual environment, as is the case with digital didactics.

Although modern technological devices are capable of reproducing sensory stimuli, it must be emphasised that the current limitation of immersive virtual environments lies in their inability to reproduce the perceptual mix, which is defined as "the process of sensory integration, which transforms sensations into perceptions. The implementation of this process, which enables the subject to interpret and respond to the surrounding environment with precision, is achieved through touch, bilateral integration, motor planning and, indeed, muscle memory" (Caldin & Polato, 2023). This indissoluble link between a body's perceptual and motor capacities serves as a matrix into which memory, emotions, language and all other aspects of life fit (id.). It is from this complex network of interactions that a meaningful learning experience can originate.

The immersive reality paradigm largely exploits visual and kinaesthetic perception, which renders it inaccessible to individuals with visual impairments. While the contribution derived from technological devices and the use of artificial intelligence in the design of useful tools to enhance the autonomy and, consequently, the quality of life of persons with visual impairments is undoubtedly significant, it is necessary to highlight some of the current limitations of their application. Virtual reality has been employed for the benefit of individuals with visual impairments, with its use thus far primarily directed towards the development of tools designed to facilitate the acquisition of orientation and mobility skills and knowledge of the external environment. For instance, motion sensors and acoustic devices have been integrated into the white cane, which, through the application of artificial intelligence, is capable of assisting the visually impaired individuals in orienting themselves in space. Virtual reality has also been employed in the design of tools that simplify the immersive experience of visually impaired individuals, both in terms of feedback and interaction mechanisms. This approach has the potential to undermine both the functionality of the tool and the involvement of the user.

Some immersive reality designs for visually impaired individuals have concentrated on audio representation and haptic feedback. There are a number of studies at the international level that have analysed this particular area. For example, Ren et al. studied the design of audio and haptic feedback for mixed reality (MR) tourism applications. In contrast, Chung et al. examined the impact of spatial audio on the performance of a task requiring the user to hit a target in a 3D virtual space. Their findings indicated that spatial sound facilitates the user's understanding of the horizontal direction of the target, and that the combination of audio and haptic-based discrete haptics reduces the completion time of the task. Nevertheless, despite the pervasive utilisation of audio in the construction of immersive realities for visually impaired individuals with the objective of enhancing interaction or furnishing information in the virtual domain, there remains no established audio design system for virtual environments for visually impaired individuals (Guerreiro et al., 2023).

Conclusions

The digitisation process, which began several decades ago, has accelerated markedly in recent years due to the advent of technologies that have facilitated the development of virtual reality, thereby creating increasingly immersive digital contexts. The metaverse, artificial intelligence and the Internet of Things (IoT) are technologies that exploit various forms of digital reality (virtual reality - VR, augmented reality - AR, extended reality - XR) to enable the Internet to permeate ever greater areas of people's everyday life contexts, going far beyond mere play or social use (Di Tore & Sibilio, 2022).

In consequence of this alteration, the educational sector is also undergoing a significant transformation. The ongoing process of digitisation of Italian didactics and school contexts is supported by an extensive national and international legislative framework, based on which numerous resources are being invested, both in economic and structural terms.

However, the project of creating smart learning environments presents challenges with regard to the principle of accessibility for visually impaired students. This is primarily due to limitations in the design of digital educational spaces that meet the needs of these students, which in turn prevents them from having a meaningful learning experience.

It is evident that while there are established guidelines that delineate the principles and modalities for making the web accessible to persons with disabilities (WCAG 2.0 released in 2008, nine years after WCAG 1.0, developed by the Canadian W3C group of independent developers), the same cannot be said about the accessibility of digital environments. In fact, virtual reality has been employed primarily to design specific, simplified virtual environments for individuals with visual impairments or to implement the functionality of assistive technologies. It has not been used to enable participation in the more complex environments and behaviours present in mainstream virtual experiences, which remain effectively inaccessible to them (Guerreiro et al., 2023).

In light of the national and international focus on the promotion of inclusive education and the significant digital transformation currently underway in education, it is imperative to design accessible digital educational environments for visually impaired students.

Considering the bio-psycho-social model proposed by the ICF (WHO, 2001), which interprets disability as the product of the person's interaction with the environment, it can be argued that it is precisely the quality of this interaction in the various contexts of life that determines disability, hindering or facilitating the process of inclusion. In this context, the design and implementation of an educational intervention can be seen as a means of reducing the impact of a disability. This is achieved by identifying and addressing the variables that contribute to the discrepancy between a deficit, which is an unchangeable condition, and a handicap, which is a condition that can be mitigated or even eliminated (Caldin & Polato, 2023).

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