FROM PLATO TO VIRTUAL WORLDS. IMMERSIVE EDUCATION BETWEEN INCLUSIVE PEDAGOGY AND NEUROSCIENCE

DA PLATONE AI MONDI VIRTUALI: EDUCAZIONE IMMERSIVA TRA PEDAGOGIA INCLUSIVA E NEUROSCIENZE

Delio De Martino
Università di Foggia
delio.demartino@unifg.it
0000-0003-3107-1816
Maria Clara Dicataldo
Università di Foggia
mariaclara.dicataldo@unifg.it
0000-0001-6999-4128
Marilena di Padova
Università di Foggia
marilena.dipadova@unifg.it
0000-0002-2105-7095
Sergio Bellantonio
Università di Foggia
sergio.bellantonio@unifg.it
0000-0002-0399-5563

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ABSTRACT

The origins of the immersive education's debate go back to classical times. Starting from the myth of the cave, described by Plato as the condition of living in an "immersive virtual reality," neuroscience could help to understand the differences at the neuronal level between a real and a virtual educational experience.
In the Metaverse age, it would be useful to investigate the immersive experience also through neuroscience to better understand its cognitive, inclusive-pedagogical effects.

Il dibattito sulle origini dell'educazione immersiva risale all'epoca classica. Partendo dal mito della caverna, descritto da Platone come condizione di vita in "una realtà virtuale immersiva" le neuroscienze possono aiutare a comprendere le differenze a livello neuronale tra un'esperienza educativa virtuale e una reale.
Nell'era del Metaverso, sarebbe utile fare ricerca sull'esperienza immersiva anche attraverso le neuroscienze per meglio comprendere gli effetti cognitivi e inclusivo-pedagogici.

KEYWORDS
Immersive technology, education, neuronal effects, Plato.
Tecnologia immersiva, educazione, effetti neuronali, Platone
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Introduction: Pedagogy and Neuroscience dialogue[1]

«Il pensiero costretto all'interno delle singole discipline ha evidenziato sintomi di malessere». Callari and Londei (2003) wrote so already 20 years ago about the need of a multidisciplinary approach in educational research.

Actually pedagogy and didactics have been sciences in dialogue with other sciences even before. Although the Italian academic "encyclopedic" enlightenment vision of knowledge (Nigris, 2017, p. 127) is still based on a rigid separation of disciplinary sectors, nowadays the multisciplinary approach is almost mandatory not only in education but also in most of academic research as well in the professional daily educational work (Cinque, 2020).

At first glance it appears clear that in the 1900s the multidisciplinariety intensified. But actually it started yet in ancient era.

In the history of pedagogy it is evident that the origins of the current dialogue of pedagogy could be found in the classic philosophy. Privileged links of educational studies there have been with the humanistic field of knowledge (the "soft sciences" area). Philosophy but also linguistics, literature, sociology, history and above all psychology among the others have been considered the nearest discipline for the study of education. It is sufficient thinking about the fathers of pedagogy - Piaget and Vygotskij are both from the psychologic area - to realize how close to the humanistic field modern pedagogy is.

In the last decades of '900s, pedagogy has started to dialogue more and more also with the "hard sciences" such as medicine, mathematics, physics, physical education (cfr. Gage, 1985).

This dialogue has projected the pedagogy in a more complex but also stimulating perspective of research and today could help to answer the questions emerging from the very fast educational technology transformation. So today there is "A Place for Neuroscience in Teacher Knowledge and Education" as the title of a recent article claims (Dubinsky et al., 2022) underlying the essential role of neuroscience for the study of the student's brain and identifying neuroscience as important root of the "teacher knowledge tree" (Fig. 1).

[1] Although all the authors have collaborated on the article, D. De Martino has written the *Introduction* and § 1, M. C. Dicataldo § 2, M. di Padova § 3, S. Bellantonio the *Conclusions*.

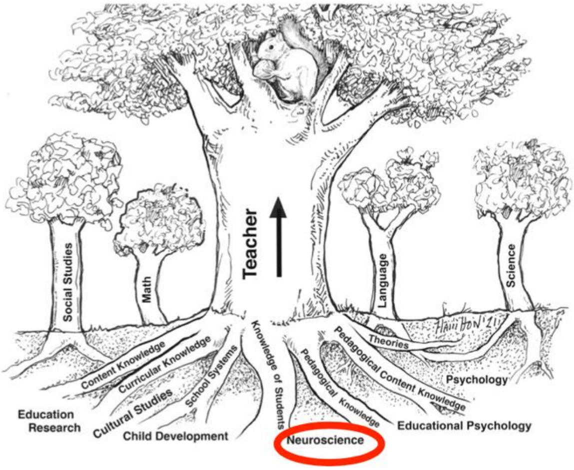

Fig. 1. From Dubinsky et al., 2022, p. 269.

So new methodological approaches appear needed in the middle of a digital revolution, even more delicate in the post-pandemic era. Between the newest technologies overwhelming the learning environments the virtual realities technologies are taking on a primary role in the future of education. Anyway the virtual realities are yet starting to be investigated by neuroscience as a useful tool (for mental health for instance, cfr. Sokołowska, 2023) and in the field of education too (Chen, 2020).

The focus of this article is the analysis of virtual realities in a bigger transdisciplinary perspective. Starting from the philosophy to arrive at neuroscience, we'll try to underline the interconnection and the mutual enrichment that the dialogue could provide to pedagogy and to neuroscience too to go into detail of the virtual realities. Interconnecting philosophy, pedagogy and neuroscience a theoretic pedagogy-humanistic framework could supply a solid starting point to neuroscience to analyse the topic as well as neuroscience could supply an empiric and technic-scientific litmus test to the pedagogic research hypothesis.

The aim is to show how transdisciplinarity could bring to a new epistemology overcoming separations between pedagogy and neuroscience and more in general between soft and hard sciences. The transdisciplinarity epistemology could be able to join the historic and theoretic research with the advantage of quali-quantitative methods of neuroscience.

1. The virtual reality: a new and an ancient theme

The virtual realities and especially the immersive augmented reality are the next big thing (Pesce, 2020) in the field of education technology. Nowadays we have the perception that we are on the threshold of becoming a new revolutionary technology able to revolutionize education.
The major taxonomy of the virtual realities has been yet studied and built by Milgram (et al., 1995) in 1995 (Milgram et al., 1995; Curcio et al., 2016):

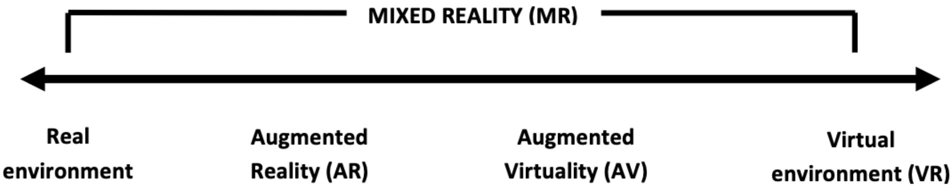

Fig. 2. Milgram Taxonomy.

Augmented reality, augmented virtuality, virtual environment have been a theme of research and application since the middle of ’90 in school and university.
To these traditional levels of virtual realities today we should add the diminished reality, a reality in which the digital information instead of adding delete something erasing from the reality (Cheng, 2022), experimented in education too (Ienaga et al., 2016), also in a inclusive perspective (Yantac et al., 2015).
These virtual realities have been developed in the half of the last century. Between 1965 and 1968 Ivan Sutherland developed the first Ar device, the “sword of Damocles” (Boas, 2013) and Lanier, founder of the first VR company VPL research, coined the expression “virtual reality” in 1989.
Today the tech industry is starting to integrate the different types of virtual realities in a more immersive way through new devices such as head-mounted displays (HDM). And only nowadays the immersive technologies appear ready to create a new and innovative third space of education (Potter & McDougall, 2017).
In 2022-2023 in a mass TV commercial Meta has promoted the future use of the Metaverse with an explicit reference to the application in the educational context. A spot shows a boy using a headset for the Metaverse. In this virtual reality that creates an immersive learning environment and presents it almost identical to an academic hall. Then it appears a virtual operating room and a walk through ancient Rome.
The voice over says: «Some people say the Metaverse will be only virtual. One day this lecture hall will be made of code and although they are virtual students what they’ll learn together is real. A surgeon will be able to practice as many times as

needed in the Metaverse before laying her hands on a real patient. These students aren't really back in 32 BCE but they still watch Mark Anthony debate in ancient Rome».

This final slogan «The Metaverse may be virtual but the impact will be real» is explicative because it raises a neuroscientific question: are there (neuronal) differences between virtual and real lessons, especially when the virtual is used by an immersive headset (as Oculus VR)?

To answer we could start from the first complete and successful reflection about education and "virtual reality".

The "myth of the cave" is the first text of western culture history where it presented the hypothesis that an immersive virtual reality could be the normality of daylife in education and in social life.

In this text Plato presents as normal the situation of students living in a sort of total immersive learning environment virtual context. An environment so pervasive that it appears perfectly transparent to the students.

Infact Plato imagines a cave where some prisoners are forced to live since their childhood in a cave chained with legs and necks locked. Their eyes are directed towards the back of the cave. They have a fire behind so they only can see the projection of the shadows of some objects sliding behind them.

So instead of looking at the real environment they gaze at the shadows of real objects.

The platonic dialogue (*The Republic* VII 514b-515d; trad. Shawn Eyer) is overwhelmingly interesting because the question is presented related to education. Socrates speaks to Gaukon about the problem of the effect of learning and of false learning:

> SOCRATES: And now allow me to draw a comparison in order to understand the effect of learning (or the lack thereof) (παιδείας τε πέρι καὶ ἀπαιδευσίας) upon our nature. Imagine that there are people living in a cave deep underground. The cavern has a mouth that opens to the light above, and a passage exists from this all the way down to the people. They have lived here from infancy, with their legs and necks bound in chains. They cannot move. All they can do is stare directly forward, as the chains stop them from turning their heads around. Imagine that far above and behind them blazes a great fire. Between this fire and the captives, a low partition is erected along a path, something like puppeteers use to conceal themselves during their shows. (514b).

In connection to neuroscience it is very interesting the reflection about the vision of the shadows, perceived as the real world.

Socrates: Then, undoubtedly, such captives would consider the truth to be nothing but the shadows of the carved objects. (515c).

In their mind they perceived the false-virtual vision of the word as the real world. This false type of perception became more real than reality, as Socrates clarifies when imagines that some captives set free and finally are able to see the "sun", metaphor of the real knowledge:

SOCRATES: Look again, and think about what would happen if they were released from these chains and these misconceptions. Imagine one of them is set free from his shackles and immediately made to stand up and bend his neck around, to take steps, to gaze up toward the fire. And all of this was painful, and the glare from the light made him unable to see the objects that cast the shadows he once beheld. 515d What do you think his reaction would be if someone informed him that everything he had formerly known was illusion and delusion, but that now he was a few steps closer to reality, oriented now toward things that were more authentic, and able to see more truly? And, even further, if one would direct his attention to the artificial figures passing to and from and ask him what their names are, would this man not be at a loss to do so? Would he, rather, believe that the shadows he formerly knew were more real than the objects now being shown to him (τὰ τότε ὁρώμενα ἀληθέστερα ἢ τὰ νῦν δεικνύμενα)? (515c-d).
GLAUKON: Much more real. (515d).

"Ἀληθέστερα" ("more real") is the comparative form in ancient Greek and refers to "τὰ τότε ὁρώμενα ἀληθέστερα", "the shadow seen before". These "virtual" shadows are "more real" compared to "τὰ νῦν δεικνύμενα", the "things just shown", in other words the just seen real object in the real word. Ἀληθέστερα has also the shade of meaning of "more sincere, fairer" that in an essential concept in the education field.
This comparative could be the key word for starting crucial questions the neuroscience could investigate in partnership with pedagogy: how far is the virtual world from "real" knowledge? Is the platonic stigma about virtual realities still alive and could it be overcome?
At the same time the term raises another question: could virtual worlds become more real than the "real" world? Until what point do virtual digital experiences correspond to real experiences? Which differences are detectable?
In this way neuroscience is a precious ally to empirically verify the real neurological impact of the virtual immersive world for the brain? Could a virtual world entirely substitute a real world also in terms of education?
Summing up, the main all-embracing question is the same as Plato: are the "virtual shadows" a false education?

The answers to these questions raised by philosophy could be given by neuroscience in an empirical way. For research through electroencephalography recording behavioral and electrophysiological responses in virtual reality and assessing the increasing sense of presence (cfr. Marucci, 2020) should go into detail of the specific area of education.

Fig. 3. The myth of the cave.

2 Virtual reality: the visual system

Today, virtual reality (VR) has progressed from the 1900s simplistic slide display to an innovative wearable device that generates a three-dimensional environment able to be manipulated by the user in a seemingly real or physical way (Scott et al., 2022).

The head mounted device (HMD) category of Extended Reality (XR) technologies can be classified as immersive or semi-immersive, practically referring to which degree real surroundings are visible to the user or not.

The HMD, through a display placed in front of each eye, can digitally manipulate stereopsis to simulate a depth component recreating how we normally see the real world.

Through head tracking functionality, HMDs can combine stereopsis with visuospatial scanning behavior such as head turning and body posture adjustments. Since motor abilities and tactile perception represent the only way of manipulating the objects in our surroundings, XR technologies generally make use of complex and precise interfaces to users' hands, fingers and tactile perceptions.

Thanks to the combination of hand interaction with virtual objects, stereopsis and head tracking, XR users have the feeling of being actually present in the virtual world, also known as immersion (Hushagen et al., 2021).

As humans we perceive our surroundings through our senses. In order to replicate a real world or the feeling of being immersed in the real world while using VR, it is important to understand which stimuli the brain processes and how (Górriz et al., 2020). Vision is the primary human sense for gathering information about the world and the surrounding environment (see Figure 4). In the back of the eye (retina) there are photoreceptors, which receive about 10 in the 9th bits (125 megabytes) of visual input per second and which initiate the process by absorbing electromagnetic radiation between 400 and 780 nm. There are two main types of photoreceptors: rods and cones. While rods are sensitive to luminance, cones are sensitive to different wavelengths of light, thus forming the basis for color vision. Furthermore, there are three types of cones (R, G, B). «Each photoreceptor in the eye is connected to a retinal ganglion cell (RGC, neuron), which transmits information from several photoreceptors based on their pattern of input. These RGCs typically have a centre-surround firing setup. If a RGC is "on centre and off surround" it will fire (initiate action potentials) when stimulated by light in the centre, which is the photoreceptors' signal for stimulation» (Figure 4 on the right) (Hushagen et al., 2021).

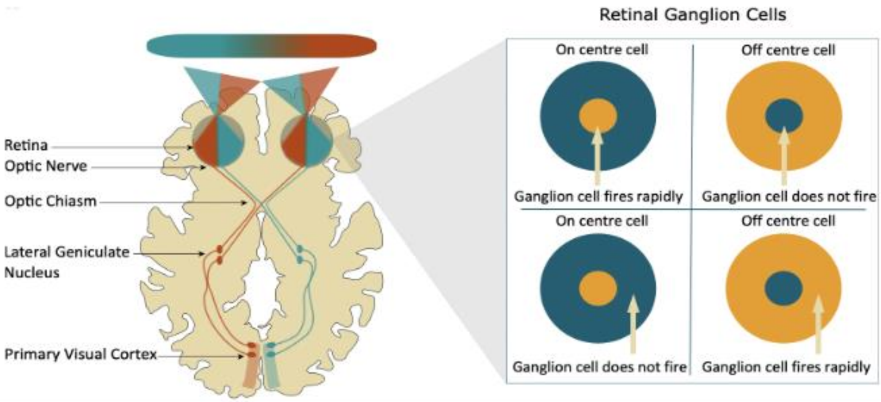

Fig. 4: The visual system. From Hushagen et al., 2021, p. 3.

2.1.1 The Optic Nerve

«The optic nerve, situated in the back of each eye, is formed by the axons of the RGCs. The optic nerves cross in the optic chiasm, with information from the right half of the visual field travelling to the left visual cortex and the left visual field (of each eye) ending up in the right visual cortex (see Figure 4 on the left). After crossing the optic chiasm, visual stimuli pass through the lateral geniculate nucleus (LGN) in the thalamus. The LGN boosts the signal-to-noise ratio from the retinal input, strengthens centre-surround interactions and acts as a gateway for visual stimuli to reach the cortex. The primary visual cortex in each hemisphere receives input from both eyes, but only one visual field, respectively the right and left side of the visual field» (Hushagen et al., 2021).

2.1.2 Primary Visual Cortex

The primary visual cortex is located in the back of the brain in the occipital lobe, also known as V1 or the striate cortex (see Figure 5). V1 is a hub, it receives all visual input and passes it along to other cortical areas that are higher in the processing hierarchy of the visual system for further processing.

V1 sends the main load of information to V2, representing the next level of processing before sending to higher cortical areas. The visual field representation contained in V2 is topographically organized, representing at least 80 of the contralateral visual fields. Further, the visual area V3 represents 30-40 of the central visual field.

Fig. 5: The organisation of the primary visual areas in the brain. From Hushagen et al., 2021, p. 4.

From V1 until V3 processing of visual information splits progressively into two pathways: the dorsal ("up") and the ventral ("side") stream (see Figure 6).

The dorsal stream is responsible for "where" stimuli are in a scene and making that information available to cortical areas involved in motoric movement. The dorsal stream proceeds from V1 up towards parietal areas of the brain.

The ventral stream is mainly responsible for perception of objects, understanding "what" is in the visual scene. The ventral stream originates in V1, moving to V4, and continues to the posterior inferotemporal cortex (TEO), which responds to patterns of luminance, relative motion, and texture differences. The stream proceeds to the

inferior temporal cortex (TE) which codes for particular features that are present in an image or object and together represents the complete representation of the object.
V4 is connected to V1, V2, V3, MT and TEO, it is involved in both streams and is sensitive to stimuli of different color and shape. Both visual streams utilise binocular disparity in depth processing, but to different extent. While the ventral visual areas are responsible for the processing of 3D shapes, the dorsal areas are responsible for the processing of long surfaces, rotation, and differentiation of depth planes.

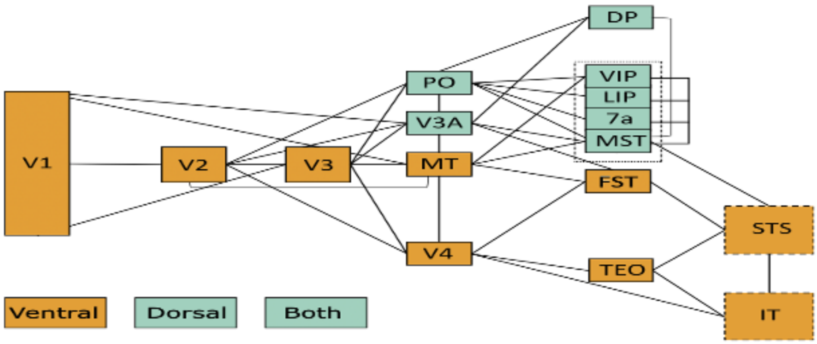

Fig. 6: Highlights the major connections between these areas. From Hushagen et al., 2021, p. 4.

2.1.3 Visual Stimuli

The properties of the visual stimuli that are coded from the retina to V1 are: color (RGB), brightness (centre/surround, RGCs) and their spatial localization in the visual field.
Color processing is a continuous process which starts in the retina, moves through V1 and V2 and then arrives in V4/V8 which are located in the lower part of the occipital lobe at the back of the brain (Figure 5). The cue of brightness/illumination, necessary for sight, is processed in V1. Spatial localization is coded from the retina and represented topographically in the primary visual cortex, V1.
Furthermore, some of the second order visual cues relevant to perception of objects and depth are: motion, shading, texture, familiar size, blur, occlusion.
These visual cues are combined together, and are necessary in differentiating and organising shapes into objects in the visual scene.

2.1.4 Perceptual Organization

Through the use of some cognitive principles, visual perception is able to extract the meaning from a scene. Figure ground segmentation relies on the perceptual separation of objects from each other and from the background. This process is essential when constructing a visual scene from visual cues. The gestalt school tries to explain how objects and scenes perception occur, with a focus on "totality". This embodies viewing all parts of the visual scene and conscious experience as an interconnected system of dynamic relationship. The main gestalt principles include: Emergence, Reification, Multi-stability, and Invariance.

2.1.5 Depth Perception

Perception of depth is very important in order to perceive the structure of objects and create a representation of the surrounding environment. This process requires the contribution of multiple visual cues and gestalt principles, dependent on the organisation of the scene. The depth perception is triggered by stimuli known as monocular or binocular cues, depending on whether the input comes from one or both eyes.

Monocular cues enable perception of depth by stimuli from one eye and the relative depth perception is based on gestalt cognition and several of the second order visual cues (motion, shading, texture, size, shadow, blur and occlusion).

Binocular stimuli are the foundation of stereopsis, and they are responsible for the reproduction of the feeling of depth created by seeing the world summarised from two slightly different images present in each retina. This process is based on disparity. «The disparity of a point on an object refers to the difference in retinal location of that point between the right and left eye, also called absolute disparity». Disparity can also be relative, which refers to the angular difference between where two objects fall on the retina.

«Binocular disparity plays a central role in perception of depth, with distorted binocular disparity leading to dramatically reduced depth perception accuracy» (Hushagen et al., 2021).

2.2 Virtual reality: impact on learning

So far it has been discussed what happens in the brain when using VR devices. But the use of such technologies has an impact on learning performance as well. The article intends, in fact, to investigate the pedagogical implications and effects of VR on learning.

Recently, information and communication technology (ICT) was introduced as a major tool for learning as the case of VR technologies (Kim et al. 2021) which are being used, in recent years, with increasing frequency for education, diversion, and distraction (Scott et al., 2022), making learning more dynamic and engaging (Budhwani et al., 2021).

Through the use of specific devices like Oculus Quest, VR allows individuals to immerse themselves in a simulated reality while engaging with it realistically through the use of the individual's gesture (Scott et al., 2022).
Neurological and psychological studies have shown that the brain creates a mental map of an environment through the use of our senses: sight, smell, hearing and touch (Bijlenga et al., 2019). The more information we try to take in, the more our cognitive ability improves because our brain observes familiar things and it can predict what will happen next. VR improves the neural connections necessary for learning and memory, thus allowing students and trainees to learn quicker and more efficiently. VR has the ability to prompt emotional reactions that enhance the user's capacity of learning (Thapa et al., 2020).
The process of attention and working memory are interlinked and, in fact, they may involve overlapping of neural mechanisms. Working memory (WM) is the ability to maintain information in the absence of sensory input. While attention is the process by which a specific target is selected for further processing and the neural resources directed towards that particular target (Bhamani et al. 2019).
The working memory develops during childhood itself, meaning that the memory capacity increases throughout childhood and adolescence which are very crucial spans of time for the development of cognitive abilities and complex reasoning included (Budhwani et al., 2021).

3. Immersive teaching: a bridge between reality and education in the new 'learning caves'

The advent of augmented reality (AR) and virtual reality (VR) technologies enable the creation of new learning environments. Modern innovations have facilitated the increase in access, connectivity, and collaborative experiences that go beyond the physical boundaries of the surrounding reality. As a result, hybrid forms of teaching have developed. These methods prove to be authentic and positively effective; despite being considered an 'irregular' learning environment (Slee, 2011). In fact, within the school walls is the most natural location for academics. It realises the dynamics and learning processes linked to teaching, making it the main place deputed to education. There are, however, special situations for which a student cannot attend school regularly. In relation to the Platonic myth, these 'irregular' learning contexts could be considered as new caves in which students are excluded from the community they belong to. The students could, then, only live and experience the shadows of everyday life removed from them. One example is the paediatric wards of hospitals where young patients are isolated from their families

and friends, deprived of the routine of daily life, and experience significant needs beyond those related to medical treatment (Hopkins et al., 2014).
Educational assistance programmes and services, such as School in Hospital, are provided within the hospital to mitigate the loss or reduction of learning during extended hospital stays. The peculiarities and needs of hospitalised students led the scientific literature to direct its research on alternative approaches to teaching/learning processes (Nicholas & Chahauver, 2017), using technological innovation to keep patients connected to school and social activities. Technology stands as a possible bridge of contact between hospitalised students and their formal learning contexts. The possibility of implementing ICT-based didactic interventions in the hospital would endorse the construction of environments oriented towards learning, but also towards the well-being of young in-patients. In addition, the online classroom setting stimulates the motivation to learn and facilitates the return to school. For caregivers, a key objective is to bridge the gap between this vulnerable patient population and their peers. Apart from the treatment of disease, caregivers can further advocate for their patients by encouraging this opportunity of scholarly growth. VR technology can help fulfil this connection by crossing the real-virtual boundary without any physical risk to patients. This fosters their inclusion in the educational settings by allowing children to connect with their external environment or to have experiences that would otherwise not be possible due to isolation. VR represents an interaction mechanism that acts as a motivational factor for adolescents, promoting positive interactions with their peers within a safe and engaging virtual environment (Curcio, Dipace, Norlund, 2016). Hospitals and schools are complex and delicate contexts. They require in-depth reflection to achieve a valid and non-disruptive immersive teaching presence.

3.1 Immersive reality experiences in the hospital school

In recent years there have been important experiments on the use of immersive reality to support learning during long-term hospitalisation in paediatric wards. The studies have shown that the use of this technology is able to positively influence the behaviours and attitudes of the people involved, favouring the creation of virtual co-learning environments (Maloney et al., 2021).
Among the various experiences carried out, a prototype, called Live Interactive FramE (LIFE), has been proposed in Spain. LIFE aims to apply an Ambient Assisted Living (AAL) paradigm to a targeted scenario of hospitalised children (Antón et al., 2015). AAL refers to the use of advanced technologies and inventive solutions to improve the quality of life of frail people. AAL provides support and assistance in a

proactive and personalised way by enabling the debilitated to live autonomously and independently within their home (Cicirelli et al., 2021).

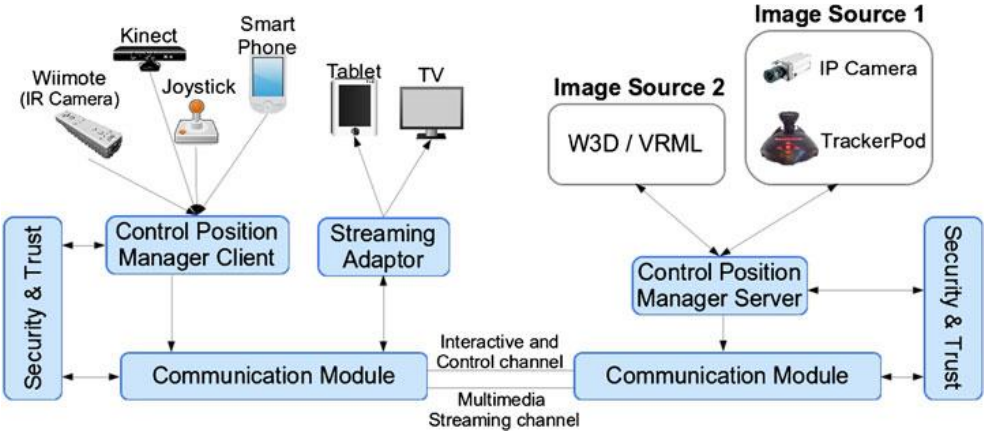

Fig. 7: Immersive view reference architecture of LIFE. From Antón et al., 2015, p. 3.

The primary objective of the experiment is to reduce stress and isolation during the hospitalisation period. This variable is affected by the participation of school activities through live multimedia streaming. LIFE simulates a virtual window on a predefined location to provide an immersive effect. Another advanced feature is control of the images from both the source and the playback, changing the framed portion of the classroom according to the patient's view.

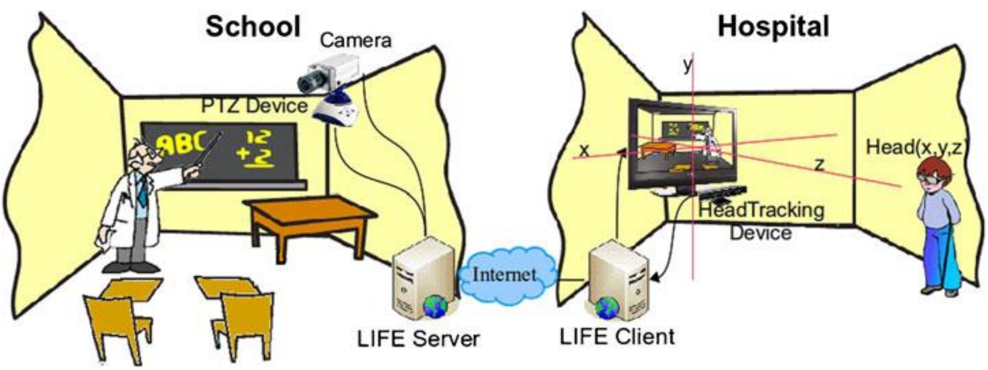

Fig. 8: LIFE application scenario. From Antón et al., 2015, p. 5.

The intention is to make the hospitalised student feel part of the classroom. LIFE is considered a practical and safe media streaming solution due to the performance evaluation and functional and safety aspects. It is possible for hospitalised pupils to reduce their sense of isolation and to truly blur the line between real and virtual in an everyday dimension, which would otherwise have been precluded to them.

A particular interest for connection and sense of belonging can be seen in New Zealand, where the Patience project was initiated (Chubb et al., 2021). In this study, scholars work with a group of hospitalised adolescents, aged 12 and 18, subject to a significant illness prohibiting them from a normal social life and attending school. Caregivers and teachers from a home school were also involved in this investigation. There were four aims to improve the management of: anxiety, hospital routine, discharge requirements, and school reintegration. The trial involved immersive telepresence technology. It links the student with a chosen educational environment through six different cameras to live-stream the full view of the classroom. The camera is manipulated by the student to enhance navigation. Interaction is enabled by text messages. Based on the experiment, young people can experience an alternative form of presence in their normal classroom environment. The results also suggest that this is an effective intervention in improving mood through increased human connection. Subsequently, between 2019 and 2020 the Patience project further implemented a technology, referred to as Immersive Reality Experiences (IRE). IRE utilises 360-degree immersive live-streaming and a virtual reality headset (Thabrew et al., 2022). This trial also showed that immersive VR technology has the added potential to enhance the social inclusion of young patients (Maloney et al., 2021).

3.2 Immersive teaching design in the hospital school

In the Platonic cave, prisoners live chained up and have a perception of their surroundings thanks to the fire that casts shadows on objects. Similarly, children and young people are forced to live a different everyday life in hospital rooms in respect of the rest of the community they come from. They experience the outside world through dialogue that takes place mainly with the help of digital devices. For this reason, it has to be asked how a virtual digital experience can be made verisimilar. At what costs? What benefits? Neuroscience helps pedagogues solve the enigma of the impact of the virtual world, but what kind of education and training do pedagogues think would be appropriate for these new learning environments? What is the most appropriate design for architectures intended for innovative learning, that is necessarily authentic and meaningful?

VR has emerged as a networked shared space for teenagers where to interact, socialise and learn. It attracts adolescents because of the wide range of engaging activities, the diverse expressive and communicative opportunities, and the heterogeneity of users in terms of age and interests (Maloney et al., 2021). Over the past few years, formal and non-formal learning activities have become the focus of investigation in hospital social learning experiences as well. Indeed, there are numerous learning opportunities (Berti, 2021):

- creating realistic simulations of complex situations;
- enabling students to practise in an engaging, interactive, safe and controlled environment;
- making access to education more equitable by providing educational resources in a more affordable and accessible way;
- offering the possibility of learning anywhere, anytime.

However, the educational design based on the use of immersive reality requires careful and detailed planning, aimed at creating a valuable and impactful learning experience for hospital students. It is important to identify the learning objectives and skills to be conveyed and to meet the needs of hospitalised students. Subsequently, it is also necessary to select the appropriate technology from those available (VR visors, VR gloves, position trackers or others) in order to create a learning experience that could be compatible with the teaching resources used. The content should also be chosen carefully, so that it is relevant, of high quality and adapted to the particular patient need. Once the activity has been created, it is important to test and evaluate the learning experience. The focus of the learning experience is on the learner's feedback, which is useful to improve the training proposal. Finally, there is the possibility of implementing the VR space with gaming technologies that enhance the social engagement of these adolescents, by promoting positive interactions with their peers within a safe and gamified virtual environment (Udapola, 2022). However, some challenges may arise during the design and implementation of such programmes. The purchase of particular VR technologies and the creation of content may require significant investments. The use of VR, moreover, requires specific training for teachers, who have to learn how to use such technologies, by changing their teaching. Students, then, may find it difficult to navigate in a complex environment and to interact with virtual objects and people in a natural way. Some people may also experience side effects such as nausea and dizziness when using VR, which may limit the duration of the learning experience. Finally, the ethical issues related to the use of such equipment in the paediatric age group and, especially, in the hospital environment should not be overlooked.

It is therefore necessary to reflect thoroughly on the possibility of experimenting with a didactic and communicative model, that is based on the use of immersive reality within the hospital setting. Neuroscience can guide pedagogical reflection in creating a strategic connection between psycho-pedagogical and medical knowledge, in order to create new learning environments as integrated forms of care.

Conclusions

In the Metaverse age, the students are more and more immersed in new learning environments that tend to be everyday more immersive and innovative. The nowadays hybrid VR-AR learning environment appears similar to the platonic cave, where the shadows are not yet analogic projections but digital data. The on-life perspective of the new technologies is that of a (digital) learning caves which enable new inclusive possibilities to the human perception and education. So, for instance, a hospital could be an immersive learning environment as a traditional classroom or a university hall. The new research on this immersive-digital-cave, even more complex, multi- and transdisciplinary requires nowadays a complex epistemology approach where pedagogy fuses together with neuroscience but eventually also with more soft and hard sciences in a panoptic perspective similar to the ancient era one. From time to time according to the fields of investigation, neuroscience can effectively dialogue with other science but also with more specialised pedagogical fields such as history of pedagogy, special and experimental pedagogy. The teacher, therefore, has the task of incorporating these demands, in order to initiate new perspectives and scenarios in teaching with a view to education for all.

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