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Virtual Reality and the Metaverse as Educational and Technological Mediators for Medical and Scientific Education

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Virtual learning simulations are gaining prominence as a supplement to traditional teaching methods, offering several educational advantages. These simulations facilitate access to advanced training equipment and immersive scenarios, overcoming resource limitations and safety concerns. As a result, students show increased motivation, growing interest in science, and better learning outcomes. In the midst of this evolution, Centres for Teaching and Learning play a key role in fostering relationships between educational institutions, research, and educational training. The experiments described in the article focus on the integration of visors and Metaverse, examining the impact on learning outcomes in biotechnology and anatomy. Although virtual reality (VR) labs enrich theoretical knowledge when used in conjunction with traditional lectures, they do not completely replace teacher-led classes, emphasizing their value as complementary tools. In both experiments, it is crucial to highlight that the tool's suitability aligns with the specific instructional process based on the tool's intended purpose. For instance, in biotechnology, the visor serves the function of anticipating laboratory practices, while the latter tool aims to reinforce these practices. In conclusion, the paper underlines that virtual methodologies are devices intended to enhance knowledge of reality, optimizing it, not offering themselves as an alternative to it. The effectiveness of using VR visors and Metaverse depends on comprehensive instructional design. Integrating these technologies into a pedagogically oriented vision is intended to help teachers and tutors optimize their use to enhance student learning, an imperative for the changing educational landscape.

Keywords: head-mounted displays, high education, blended learning

Educational Innovation Occurs Within Relational and Systemic Contexts

Teaching innovations, in order to be authentic, require that digital methodologies and tools are not introduced in a parcelled or sporadic manner. There is a need for them to be part of the construction of learning

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systems in which relationships, in all their facets, are the backbone. In fact, schools are rediscovering the importance of new participatory approaches in which students are at the centre of teaching (Pasta & Rivoltella, 2022).

At the systemic level, designing learning (learning design) means “creating the environment and conditions in which students find themselves motivated and enabled to learn” (Laurillard, 2013, p. 66). For Laurillard, central to teaching is not only the content but also the design of this content. To this end, digital technologies are not only considered as tools and sources for learning. Because of their ability to create environments for learning, they can also be valued as design tools. Digital tools, like the teaching methodologies in which they are embedded, must become the mainstay in the construction of interdisciplinary and vertical curricula that start from primary education and reach university education with the different declinations that each level and grade requires. Competency-based and digital teaching, in order to be effective, should be chorally promoted in formal and informal educational settings, as competence by its very nature must be continuously implemented according to designed and consequent levels. Achieving this is not possible through a mere adjustment of the registry age or educational grade.

Designing and evaluating for competence requires careful reflection on the different levels of knowledge, on how it is possible and practicable to overcome a didactics focused on memorization, repetition/reproduction of knowledge through the proposal of conceptual, complex and/or practical-complex tasks, which gradually shift the design from knowledge-centered objectives toward simple skills and, progressively, in the direction of complex skills that can contribute, especially if solicited and practiced (with the possibility of reiteration of attempts) in motivating and real or realistic situations, to the development of competence (Cardarello, Nigris, & Salvato, 2023).

In comparison with planning carried out in traditional form, the digital form offers greater flexibility in the transitions between macro-planning (curricula) and micro-planning (lessons), in the arrangement and organization of the various elements that are part not only of the project itself, but also of the processes of implementation, such as resources, tools, spaces, etc. (Grządziel, 2021).

In this educational and socio-cultural context, particularly in the aftermath of the COVID-19 pandemic, it is believed that relationships in their different declinations are a key aspect we need to ask ourselves about, in addition to systemic design, in order to create true innovation. Often one realizes the value of something only at the very moment one is deprived of it, which is probably why the emphasis on the importance of the relational fabric and related skills, three years after the start of the pandemic, is so present. When analyzed as a communicative event (Moore, 1989), the teaching event takes place in the ternary interaction between teacher, students, and knowledge, and can be decomposed into two interdependent dimensions, the relational and the content dimensions (Schneuwly, 2007).

The relational dimension refers to the relationship that teachers and students have with each other and with knowledge, but relationships also constitute an area for study and reflection in terms of collaboration between different levels of education, with the world of work, and between different professions and skills. This aspect can find new areas of experimentation, starting from the pedagogical-educational context, following the solicitations that also come from the national and international academic and legislative context. The most recent indications, coming from the European Union and the National Recovery and Resilience Plan (NRRP 2021), remind us that the main task of the university is to build knowledge useful for the development of the country and to train future professionals capable of interacting with new professional constructs. Within the funds allocated in the NRRP, many activities focus on the importance of collaboration between different professions, both in research and teaching, because in an increasingly complex and rapidly changing society, such as the one in which we are currently living, it seems that only cooperation, mutual help, the union of different knowledge and skills, will be able to make it possible not to succumb to the speed with which even the technological devices themselves, such as artificial intelligence, adapt seemingly much more immediately and quickly than people can do (Fabbri, Romano, & Carmignani, 2022).

In this relational context, educational technologies can be a valuable aid and glue, if integrated in a blended approach, as Midoro argues, communities of practice can even be enhanced by the use of virtual tools (Midoro, 2002).

University teachers in particular are required to develop multiple skills and competencies that transcend the specificity of their own disciplines and be able, through a knowledge of the most innovative teaching methodologies and technological tools, to improve the quality of teaching, assessment, and their own competencies, which is why dedicated centres in universities (Teaching and Learning Centres, TLC) have also been funded. This demand to broaden one's areas and environments of action, which is being made insistently in academia today and has been proposed to teachers of all levels for many years, can be called interdisciplinarity (Fundarò, 2020) and trans-disciplinarity (Marzocca, 2014). Didactics with its digital methodologies and tools is therefore also seen as a chance to create that basic fabric that can connect and create horizontal and vertical relationships.

The TLC and the Experimentation at University of Insubria

The importance of the role that didactics plays, especially in the relational and disciplinary spheres, has been further fostered by the emergence in Italy of several Teaching Learning Centres, which deliver Faculty Development courses to increase teaching knowledge in all areas of university teaching: The TLC has over time emerged as the place to cultivate those social structures aimed at reconstructing the complexity of professional action in light of new challenges. Knowledge-based social structures have thus been sedimented. The recognition of these structures as important strategic resources to be safeguarded has been perhaps one of the most significant problems of the existing TLC. The TLC has thus configured itself as a promising device capable of nurturing socially and scientifically validated confrontation through the activation of collective intelligence, open to talk about what is happening, the socio-material aspect, and the meanings, even if contradictory or ambiguous, that each person attributes to his or her doing (Fabbri et al., 2022). With this in mind, the University of Insubria of Varese and Como has undertaken in the last two years within the Teaching Learning Centre (TLC) project, training paths for the development of methodological-didactic skills for teachers and in training programs designed to grant Open Badges to University students demonstrating the acquisition of soft skills. In addition, the TLC aims to implement activities for the third sector, particularly with secondary schools, through sharing practices and training and innovation projects with the support and integration of the most innovative technologies, promoting the development of a teaching culture inspired by active learning and aspiring to construct faculty learning communities (FLCs). This pertains to research and begins with the assignees designated by the TLC for tasks related to various degree programs. The aim is to encourage the formation of a transdisciplinary community among 10 TLC assignees from the university who belong to different departments and disciplinary fields. This collaboration is intended to bridge the gap between different areas of study and encourage a collective approach to problem-solving and knowledge sharing. The hypothesis being tested is whether establishing working groups comprising teaching staff from various educational levels can be a key tool for training teachers within a comprehensive curriculum framework. This aims to equip each teacher with the necessary teaching tools suitable for their specific level of education, fostering educational innovation through collaborative efforts. The ultimate goal is to prepare students for an ever-evolving world by implementing the collaborative and relational components of teaching staff.

Using Virtual Reality Simulations as Educational Tools

Virtual learning simulations are increasingly used in various educational and training contexts as a complement to traditional educational methods (Wismer et al., 2021). Previous research has shown that they offer significant educational benefits. For instance, virtual learning simulations provide an opportunity to use cutting-edge training equipment and learning tools that many educational institutions might not be able to provide. Moreover, virtual simulations allow students to engage in realistic scenarios that may be too dangerous, time-consuming, or expensive to undertake in real life (Thisgaard & Makransky, 2017). The advent of immersive virtual reality (IVR) through head-mounted displays is expected to further enhance virtual learning experiences (Bodekaer, 2016). With the decreasing prices of IVR devices, many companies and educational institutions are investing substantial resources in developing new IVR educational tools, anticipating that a higher level of immersion will increase student motivation (Makransky, Borre-Gude, & Mayer, 2019), foster interest in science (Makransky, Petersen, & Klingenberg, 2020), and enhance learning outcomes (Makransky, Terkildsen, & Mayer, 2019). As a result, the field of virtual learning is rapidly evolving, and there is limited current research available to assess the performances of these new IVR learning tools.

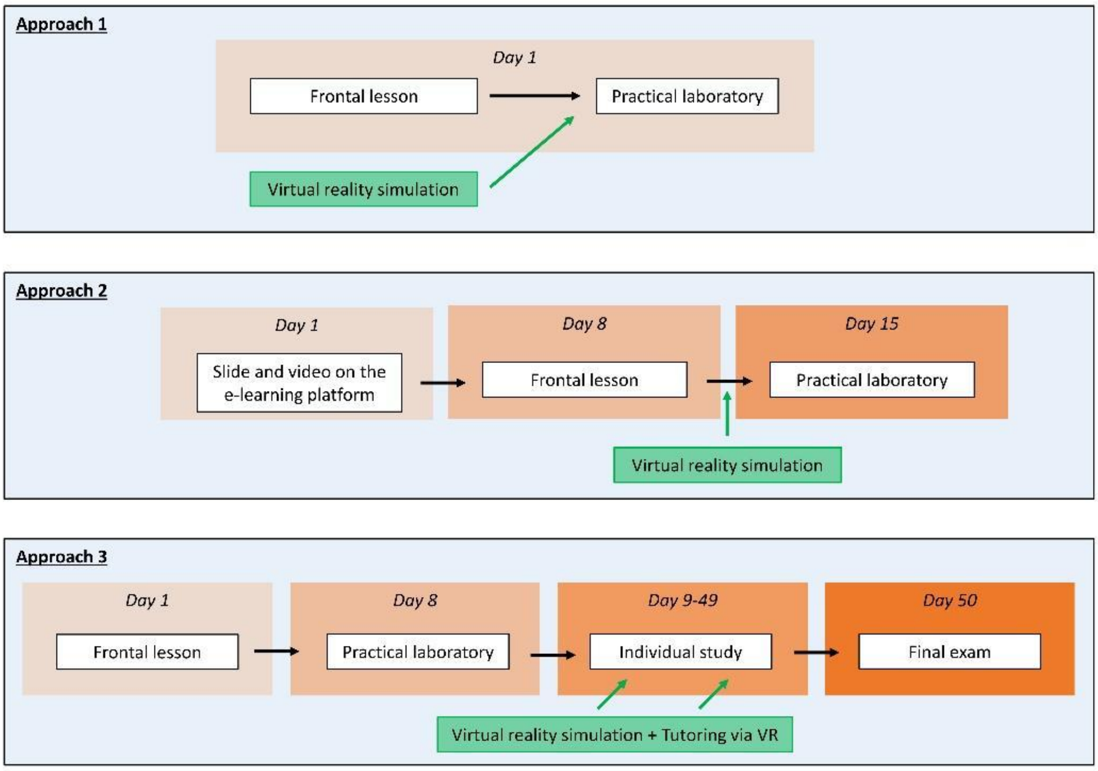

Figure 1. Schematic representation of the three different approaches under study, aimed to integrate virtual reality simulations (green boxes) in the existing educational methods (white boxes).

To contribute to filling this gap, we are conducting three independent studies to test various strategies for enhancing student learning outcomes using IVR laboratory simulations (Figure 1). The main objective of this study is to evaluate the influence of IVR technologies on student motivation and learning outcomes compared to learning with conventional methods. Theoretical knowledge, interest in science, self-efficacy, and engagement will be assessed using online questionnaires before and after the proposed activities.

Approach 1

In this first study, IVR lab simulations will be used as a tool to anticipate both the theoretical concepts and manual skills necessary in the subsequent practical laboratory. The first study will be conducted on a sample of 100 students to test IVR lab simulations as an alternative to the teacher's face-to-face lecture in preparation for the corresponding practical lab (Figure 1). Based on the available literature, we expect to observe a higher motivation in students using IVR lab simulations, without affecting the learning outcomes. Being among the first studies on VR simulations, Makransky et al. reported no differences in knowledge between groups that attended either a flat-screen virtual laboratory simulation or a face-to-face tutorial (Makransky, Thisgaard, & Gadegaard, 2016). More recently, Wismer et al. tested IVR simulations and observed no differences in the knowledge scores of the group of students that attended the IVR simulation with respect to the group that attended real-life training (Wismer et al., 2021). Further studies reported an increased interest in science (Makransky et al., 2019), self-efficacy (Makransky et al., 2016), and engagement (Parong & Mayer, 2018) following didactical activities with VR lab simulations. Our preliminary results also support these last conclusions (Figure 2); however, adding interesting features to a lesson may not be enough to enhance the student's learning outcomes (Dewey, 1913). Since VR simulations seem to motivate students more than conventional educational methods, Parong and Mayer suggested the use of IVR simulations in couple with the existing educational methods in order to increase the motivational outcomes of the learners while maintaining high learning outcomes (Parong & Mayer, 2018).

Figure 2. Results of the optional open question administered to students who used the VR simulations. The question stated: "Write 3 adjectives to describe your experience with immersive virtual reality simulations". A total of 160 adjectives were collected. Keyword frequency analysis was represented as a word cloud using the software MaxQDA (VERBI Software GmbH). A larger word size corresponds to a higher frequency of the keyword in the participants' responses.

Approach 2

In our second study, IVR lab simulations will be used as an integrative tool after the frontal lesson and before attending the practical lab (Figure 1). The IVR simulation will have the twofold task of reinforcing the theoretical concepts learned during the frontal lesson and anticipating the development of the manual skills needed for the following practical laboratory. We will test this didactical method with approximately 100 students, providing questionnaires before and after the educational path. We expect that students who will attend the IVR lab simulations will show both higher motivation and higher learning outcomes with respect to students who followed the ordinary didactical method. While it is well assessed that IVR lab simulation increases the motivational outcomes of the students (Makransky et al., 2019; Makransky et al., 2016; Parong & Mayer, 2018), fewer studies measured the learning outcomes when this approach was used. Among them, Chan et al. reported that combining VR lab simulations with face-to-face lessons results in a greater learning improvement than the traditional didactical approach alone, as it is supposed to reinforce the previously learned concepts (Chan, Van Gerven, Dubois, & Bernaerts, 2021). It is suggested that a high level of immersion and interactivity engages the student to develop a greater understanding of the learning contents resulting in higher learning outcomes (Davenport, Rafferty, & Yaron, 2018).

Approach 3

In our third study IVR lab simulations will be used as an integrative tool to recall the student's experience after attending the practical lab matched with a tutoring figure (Figure 1). The virtual laboratory will be a Metaverse space, in which students can meet and study anatomy. Therefore, the simulation has the goal of consolidating the information gained during the real-life experience through IVR sessions. We will test this didactical method with approximately 50 medical students, providing questionnaires before and after every IVR session. Also, data will be recorded from actual exams to measure the differences between the experimental group and the control group. As already tested on medical students, we expect that students who will attend the Metaverse lab simulations will feel more engaged and motivated (Gao et al., 2023), and therefore accomplish higher learning outcomes with respect to students who follow the ordinary didactical method. Compared to Approach 2, this third study leaves more room for exploring the Metaverse, creating a social and enjoyable learning environment that increases the student's enthusiasm for learning (Mokhtar, Xuan, Lokman, & Mat, 2023).

Tutorship is also proposed at this stage. Tutorship is a function performed by experienced professionals who guide, support, and assist the student; the field of action relies on the central role of experience. Through example, coaching, and reflexivity, the tutor encourages the student to develop the expected skills. Engaging in a situation, whether physical within a workshop or virtual in a simulated space, provides the immersion and involvement required to collaborate with the tutor and develop a learning activity based on feedback (Hattie, 2012) emphasizes the central role of this didactic tool in learning processes, challenging the notion that knowledge is acquired through direct explanations. Contrarily, the highest didactic effectiveness in activating learning processes has been observed in situations where reflective and re-elaborative thinking is stimulated on the practical experience facilitated by a skillful tutor who observes, poses questions, and supports the student. The tutorship activity can represent a strong glue that gives meaning to the activities by activating a relationship of trust and support.

The presence of a tutoring figure in Approach 3 is a new point of view of what Metaverse can be. The virtual environment can become a network of social interaction between present and future experts, in which the tutor, a professor, can transmit knowledge and experience in the most efficient way ever. Thanks to Metaverse tools, the professor-student relationship can defy any obstacle.

Discussion

To illustrate the interplay between physical and virtual reality, we can refer to Bonometti's framework, which categorizes four learning contexts based on the interaction of these two dimensions (Bonometti, 2023). This framework provides a deeper perspective on education, demonstrating how it can bridge the gap between physical and virtual experiences while promoting critical thinking and reflection.

The formulation of the current framework is predicated upon the interaction of two variables, which intersect to delineate, in an ideal-typical manner, four conceivable learning environments. The initial variable delineates, at the extremities of a continuum, the concept of physicality, denoting corporeal involvement within a context of tangible existence on one end, and virtuality, signifying an experiential environment characterized by progressive detachment from a physical frame of reference on the other (Bonometti, 2023).

The second variable situates, at the extremes of the continuum, the notion of reality construed as one's immediate presence in relation to others and a contextual backdrop, and, conversely, the philosophical conception referred to as "phantasmagorical". This philosophical perspective posits that, both in psychological and epistemological terms, perceptual experiences are but phantasms, distorted and divested of the semblance of reality, similar to the moving, projected shadows in Plato's allegory of the cave (Bonometti, 2023).

The matrix represents a systematic endeavour to discern criteria by which learning experiences entwined with the online domain can be diversified or tailored. Adhering to a clockwise circular logic and commencing from the top-left quadrant, the matrix identifies four distinct sectors within its framework (Bonometti, 2023).

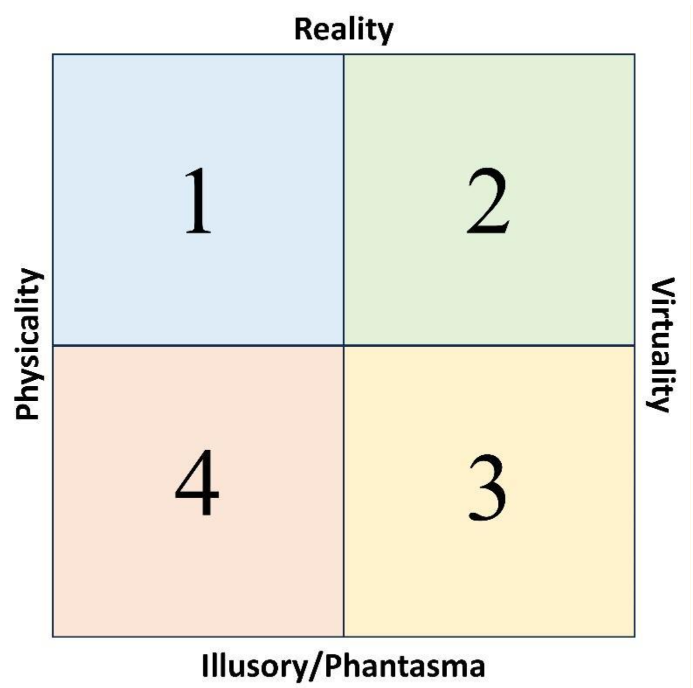

Figure 3. The matrix of learning experiences between real and virtual (Bonometti, 2023).

Box 1 delineates a conventional learning environment wherein reality and physicality intertwine. These environments embody instances where the interpretation of reality is seamlessly integrated with the immediate surroundings, and individuals engage physically with the contextual elements. Box 2 illustrates a learning dynamic where learners undergo the acquisition of knowledge and skills within a genuine, albeit not necessarily physical, setting. The proposed activities mirror reality, with the actions encountered paralleling those demanded in physical contexts. Despite the virtual nature of the context, the level of reality remains high (Bonometti, 2023).

Box 3 encapsulates what is presently associated with the Metaverse—an alternate dimension beyond the physicality of reality. Experiences fostered in this dimension possess distinct coherence, a substantial detachment from physical reality, limited control over events, and a transformative perspective on reality. Box 4 logically signifies a disassociated concrete life experience, wherein the perceived experience of an individual diverges from the concreteness of the context perceived by others. The potential for illusion arises due to perceptual and cognitive filters hindering an accurate and genuine perception of the concreteness of reality (Bonometti, 2023).

John Dewey emphasizes that education through experience aims to foster critical thinking and personal growth in learners; this concept extends to online learning, which should be integrated into everyday life; this integration contemplates a reorganization of learning content and modes of delivery and use (ANVUR, 2023).

The first sentence is stating that both physical and virtual learning environments have unique characteristics in their teaching methods. However, their complete effectiveness becomes evident when they create a meaningful path that combines both in-person presence and online elements.

The second sentence highlights the importance of understanding that the effectiveness of the instructional process involving a tool is reliant on the tool's intended purpose. For instance, in the field of biotechnology, the visor serves the function of anticipating laboratory practices, while the latter tool aims to reinforce or consolidate these practices.

In Approaches 1 and 2, the students are stimulated to a mental activation that builds an experience of anticipation and already produces a learning phase in simulation terms (Berthoz, 2015). Also, the virtual experience can improve the familiarity with laboratory tools and environment before the real lab, improving the experience learning output.

In Approach 3, the students already own all the information from the frontal lessons and real-life lab. The IVR, experienced after the practical laboratory, has the role of consolidating the pieces of information by stimulating the remembrance and the elaboration of the real experience.

Conclusions

The initial evidence that has emerged attests to the fact that virtual methodologies, however sophisticated and high-performing they may be, are not by themselves sufficient to increase better learning if not supported by a comprehensive instructional and methodological design. The experimentation with these tools will be accompanied by a reflection on their evaluation in the educational field and their potential interactions with various existing learning methodologies. The aim is to develop an integrated and pedagogically-focused vision of a crucial aspect of the development of today's society, to assist teachers in utilizing these powerful technological tools in the most effective way for their students' learning.

Three dimensions can be outlined that characterise a teaching action in the context of blended learning and support the activation of a meaningful and profound learning process. First dimension is immersivity. The experience of immersion in the enjoyment of media represents a process of involvement, of encounter between emotional and cognitive dimensions that favours a deep rootedness of knowledge, a holistic experience of learning. Immersion, beyond a specific context, allows the student to carry out "a flow experience" (Csikszentmihalyi, 2011), that experience that strengthens motivation, through the modification of the perception of time passing.

Second dimension is the value of the mistake. In this case what we wish to highlight here is the importance of the mistake as a key factor for learning, an opportunity to develop self-regulation competence, to understand the complexity of possible solutions, to open up to a co-constructive approach to knowledge.

The last driver is the playful dimension. Learning through virtual reality makes possible an experience that is very close to the playful experience lived by young people through the use of technology.

In a blended perspective, "being digital" is inextricably intertwined with "being real", in this weave the instances of space, time, relationship, and content (Rivoltella, 2022), maintaining their value by expanding it.

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