THE USE OF IMMERSIVE VIRTUAL REALITY IN A HIGH SCHOOL CLASSROOM: AN EXPLORATORY STUDY

LA REALTÀ VIRTUALE IMMERSIVA IN UNA CLASSE SCOLASTICA. UNO STUDIO ESPLORATIVO

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ABSTRACT

The article presents the results of a quasi-experiment that intends to start the investigation of the effectiveness and efficiency of using immersive virtual reality (IVR) during teaching activity. Thirty-four 9th grade students from a high school in Northern Italy were involved. The data was collected through questionnaires, assessment tests and video recordings. The results obtained, interpreted from an exploratory perspective, highlight the potential of IVR.

L'articolo presenta gli esiti di un quasi-esperimento che intende avviare l'indagine sull'efficacia e l'efficienza dell'uso della realtà virtuale immersiva (IVR) durante l'attività didattica. Sono stati coinvolti 34 studenti di una classe prima di un istituto medio superiore del Nord Italia. I dati sono stati raccolti mediante questionari, prove di valutazione e videoregistrazioni. I risultati ottenuti, interpretati in una prospettiva esplorativa, mettono in evidenza le potenzialità della IVR.

KEYWORDS
Immersive virtual reality, high school, classroom
Realtà virtuale immersiva, scuola media superiore, classe scolastica

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Introduction

Virtual reality (VR) technology has been in development for several decades. The characteristics of this new technology have led to the creation of two types of experiences: VR viewed via desktop and VR viewed via head mounted displays (HMDs). The latter allows users to experience more immersive sensations (Buttussi & Chittaro, 2018), leading to the definition of another concept: immersive virtual reality (IVR), since the aspect of immersion takes an important place, which, together with presence and interaction, represents the three fundamental characteristics of this innovative technological tool.

Immersive virtual reality (IVR) systems have been employed in multiple contexts. In architecture, as a design tool or as a means of visiting an unreachable place (Mazuryk & Gervautz, 1999); in the medical field, for example, in planning a surgical intervention (Halabi, Balakrishnan, Prasad Dakua, & al, 2020). Furthermore, several researchers have used IVR to investigate human behaviour, even for rehabilitation purposes (Tieri, Morone, & Paolucci, 2018) and mental processes in experimental psychology (Gaggioli, 2001) and clinical psychology (Riva, 2009). Among the advantages of this technology in this area, Bohil et al. (2011) highlight the possibility of immersing an individual in environments/situations that are dangerous or impossible to recreate in reality and having all his reactions controlled by the researcher. Through the IVR, it is, therefore, possible to "immerse" the individual in different environments and situations with the possibility for the researcher to control the various variables involved, such as the physiological and cerebral responses obtained during the experience. The combination of IVR with some tools used in neuroscience research allows us to study the effects this technology has on the body and brain of individuals.

Finally, evidence has already emerged about the benefits of this new technology also in the educational field: in improving the memorization of learning contents (Freina & Ott, 2015) and in increasing motivation in the study of some subjects such as mathematics (Shi, Wang, & Ding, 2019). However, to detect the potential of immersive systems, research protocols have been favoured that envisage the use of IVR with individual students or small groups and within computer laboratories or spaces built ad hoc. Recently, some authors have been wondering about the possibility of being able to use IVR with the involvement of a more significant number of subjects (e.g., a school classroom) (Cheng & Tsai, 2019), but without considering the elements concerning the actual context in which the daily teaching activity takes place. However, these are fundamental elements in the perspective of the possible widespread use of this technology in schools.

Therefore, the research objective we present is to understand if and to what extent the IVR can be considered a teaching tool to be used within a real school context without disturbing the ordinary course of activities, simultaneously involving all the students and promoting their well-being and learning.

Below we will clarify the concept of immersive virtual reality and report the results of a series of empirical researches carried out in schools to identify the fundamental elements to be considered in planning an educational activity in IVR. Subsequently, we will describe the characteristics of the empirical research carried out by describing the methodology, the results and their discussion.

1. The IVR and its applications in an educational and scholastic context

Immersive virtual reality (IVR) has recently been defined as a «computer-generated simulation of a lifelike environment that can be interacted with in a seemingly real or physical way by a person, by means of responsive hardware such as a visor with screen or gloves with sensors» (Stevensen & Lindberg, 2022). It is, therefore, a "non-real" space created by technologies (Pernekulova, Sagikyzy, Ashirbekova, & al, 2021) or a simulation/ imitation of "real and imaginary worlds" created by a "complex multimedia system" (Mikropoulos & Natsis, 2011).

Three main concepts are better used to delimit an IVR experience's multiple aspects. The first is the *presence* as "the subjective experience – that the user experiences – of perceiving himself in a place or environment, even when he is in another" (Witmer & Singer, 1998, p. 225). In particular, it is essential that the criterion of the "sense of presence" be satisfied and that the indivudual feels present in the observed environment. This way, the user will respond realistically to virtual stimuli, eliciting physiological reactions (Sanchez-Vives & Slater, 2005) (Parsons & Rizzo, 2008). Secondly, *interaction* is defined as "the degree to which a user becomes an active part of what they are viewing, modifying and interacting with the environment in real-time IVR" (Steuer, 2000, p. 10). Finally, *immersion* whose meaning is twofold: as a «technological attribute to be materially declined (Slater & Wilbur, 1997); and as a psychological phenomenon that refers to the subject's experience of perceiving himself as more or less inserted within the virtual world regardless of the characteristics of the technological devices used (Mütterlein, 2018). Has been proposed the distinction between the concept of i*mmersion*, which refers to the extent to which the different characteristics of the interfaces allow individuals to perceive only virtual reality, excluding empirical reality, and the concept of *perception of immersion*, which identifies the integration between the psychological perception of the user's presence with the level of interaction with the virtual environment (Tassinari, Marcuccio, & Marfia, 2021).

From the systematic review by Di Natale et al. (2020), the great importance of IVR in education emerges. The 18 studies included in the review – of which only four concerned the K-12 school level while the remaining 14 had the university as a reference context – demonstrate that in some cases, the IVR can support a series of experiences that improve student learning and motivation to achieve educational goals in university settings (e.g., Ekstrand, Jamal, Nguyen & al., 2018; Stepan, Zeiger, Hanchuk, & al., 2017; Klippel, Zhao, Jackson, & al., 2019) and schools (Bhattacharjee et al., 2018; Olmos-Raya et al., 2018; Shi et al. 2019; Villena Taranilla et al., 2019).

In schools, IVR has been used in different ways. The researchers preferred research designs aimed at detecting the effectiveness of IVR on learning achievements and motivation of individual or small groups of students.

Bhattacharjee et al. (2018) carried out three quasi-experimental studies to investigate the effects on biology and chemistry learning of a personalized learning path for students with different needs by applying an immersive virtual reality framework for a mobile platform. The implementation was done on cardboard viewers. The students involved were, respectively, 50 students between the ages of 15-16, 15 students aged 14-15 with Attention Deficit Hyperactivity Disorder (ADHD) and 15 students aged 13-14 with Audio Processing Disorder (APD). The results demonstrate an improvement in learning (retention and creativity) in all three cases. Only in the first two was there an improvement in the practical implementation. However, the authors conclude that the most effective model combines traditional and proposed schemes.

In the study by Olmos-Raya et al. (2018), 56 high school students between the ages of 14-16 years enrolled in a social science course (geography) were involved in a 2x2 factorial experimental design. Two factors were considered: emotional induction (positive and neutral) and immersion (low and high). The entire activity (knowledge questionnaires, emotional induction procedures, and interaction with the educational content) was divided into six modules and lasted 55 minutes. The participants were exposed to the immersive content for 8 minutes – in each module – through a viewer powered by a smartphone. The students experimented individually in a laboratory and not in a classroom. The results demonstrate that: 1) participants have better retention when positive emotional induction and high immersion occur. Researchers also found increased medium-term learning in the high immersion condition; 2) participants revealed a higher level of interest between the pre-tests and post-tests in the high immersion condition; 3) the valence scale values were higher when there was positive emotional induction and high immersion.

Villena Taranilla et al. (2019) conducted a quasi-experiment involving primary school students in a real classroom context. Researchers have introduced IVR as a tool for teaching history to verify the improvement of students' learning and motivation. The results show that the experimental group's students obtained better results in terms of learning and motivation than the subjects of the control group. M Measures were not used to detect the students' psychological reactions to IVR (presence, immersion, interaction, well-being).

On the other hand, Shi et al. (2019) carried out a pre-test–post-test experimental design with students aged between 13 and 16 using game-based immersive virtual reality learning environments (GIVRLEs). The aim was to detect the improvement in mathematics learning and motivation, the type of students' experience with virtual reality, the quality of the game (playability) and the correlation between the student's characteristics and the other investigated variables. The results reveal a statistically significant improvement in both learning and motivation. The students perceived the IVR experience as positive as the satisfaction and usability (playability) level of the virtual game. Furthermore, a significant correlation was found between extraversion and improvement in mathematics achievement and between playability and conscientiousness. In this case, however, the students conducted the experiment individually in a context different from that of the classroom.

The research by Cheng et al. (2019) appears outside the research included in the systematic review by Di Natale et al. (2020). Given its complexity, it is particularly relevant for research on IVR in the school environment. We will focus on it in more detail below.

The Chinese researchers investigated the influences of the IVR on a convenience sample of 24 primary school students and the teaching methods a teacher uses about story content. The objective of the research conducted with a one-group pretest-posttest design in a computer laboratory was to detect the level of perception of presence (*spatial presence, involvement, experienced realism*), change in motivational beliefs (*self-efficacy, intrinsic value, test anxiety*), the attitude towards learning with IVR, the instructional methods of implementation of the IVR (*implement learning activities*) and interaction teacher_students.

The students all participated at the same time in the teaching activity with IVR. However, as there were not a sufficient number of devices (DSCVR headsets with ABS plastic material) for each student, the students were randomly divided into 12 pairs. They used the VR device in turn during the teaching activity.

The results show that, to some extent, the students perceived a strong sense of spatial presence but a weaker overall involvement and sense of realism. Test anxiety decreased after the IVR experience thanks to a more excellent perception of spatial presence. Additionally, a greater sense of spatial presence encourages students to have greater confidence and intrinsic motivation to learn. The perception of spatial presence and realism had a more significant impact on students' motivational beliefs than the perception of involvement in teaching activities. Another interesting result is that the stronger the perception of spatial presence and realism, the greater the willingness of students to participate in IVR instructional activities for learning in social studies. Finally, attention to the virtual world and resulting lower awareness of natural environments (e.g., the classroom) did not play a role in students' intention to engage in IVR-related learning. In answering an open-ended question, 90% of the students expressed their satisfaction with the experience. However, one student reported feeling dizzy. Another student did not appreciate some teaching methods of the teacher. Furthermore, many have complained about the little time to experiment with virtual teaching materials before the teaching activity.

As regards the codified behaviours of the teacher, the most frequently exhibited by the teacher was explanation (instruction), asking questions, and guiding movements in virtual reality. As far as student behaviour is concerned, the most frequent was the observation of VR content. The students also frequently answered the teacher's questions. During the learning activity, internet-searching and cluttering classroom behaviours were rarely exhibited. Additionally, assistant teachers provided some troubleshooting help during the IVR experience.

Interactions between teacher and students were found only in the central phase of the learning activity. During the entire activity, the students continuously observed the contents. Still, the teacher spent little time guiding his students in navigating the IVR in the initial and final stages. This situation probably raised students' concerns about limiting the time to experience the virtual scenes before the learning activity.

The research by Cheng et al. (2019) is one of the first studies that aims to investigate how IVR technology can be applied in a real teaching context with a group of students all simultaneously involved in an IVR experience and how teachers use it in management of their daily teaching activities and in interacting with students.

However, one aspect not considered in the research of Cheng et al. (2019) - probably because it was created in a computer lab and not in a traditional classroom - is the natural setting in which the IVR experience occurs. Shifting attention to this dimension means facing the use of IVR in a natural context from an ergonomic perspective.

The attention of those who build physical spaces for learning situations and of those who design teaching tools (such as IVR) must focus on all "ergonomic aspects" that are studied by physical ergonomics (Di Nocera, 2008), cognitive ergonomics (Marcolin & al, 2002), social ergonomics (Ruggeri, Ballor, & Boca, 2019) and didactic ergonomics (Calvani, 2001; 2006)[1].

In the latter research area, particular attention must also be paid to how the body of the subject who uses IVR devices interacts within the classroom space, with the furnishings and with the other students.

For this reason, one of the research objectives we present below was to detect the students' movements while using HMD in the classroom during the ordinary educational activity.

2. Method

[1] Didactics ergonomics critically evaluate the relationships between student-machine-processes in the light of the opportunities and the physical and cognitive spaces available.

The research aim is to understand if and to what extent the IVR can be considered a teaching tool to be used within a real school context without disturbing the ordinary course of activities, simultaneously involving all the subjects and promoting their well-being and learning. For this reason, we have created a quasi-experiment carried out within a real learning context (two 9th grade classes) with the involvement of all students. The research questions are:

- Have the students had previous experience with IVR?

- Did the students perceive presence in the observed environment during the IVR experience?

- Did the students experience adverse physical reactions during the IVR experience?

- Are the learning outcomes of the students of the experimental group statistically different from those of the control group? [2]

- During the IVR experience, were the students able to interact effectively or did they suffer from limitations in their movements due to the class layout and/or the position of their classmates?

2.1 Participants

Students from two high school classes in northern Italy identified through convenience sampling were invited to participate. The subjects included in the study were 43 (F=2) aged between 14 and 15 years. The students belonged to the two first classes of the same institute. In the first class, made up of 21 male students, the intervention with IVR was carried out; the second class, made up of 22 students (F=2), acted as a control group. However, the students present on the day of the trial were in both classes 17. Both girls were present in the control group. Therefore, the data reported below refer to a total of 34 subjects.

The teacher who taught the experimental and control classes was a 50-year-old female with over 20 years of teaching experience in the science discipline. She knew the IVR for personal interest, but she had never used it, nor had she used it in a school context.

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[2] Learning achievements are one of the variables characterizing an educational experience. Nonetheless, the research focuses on the process dimensions to answer the question concerning the feasibility and efficiency of the IVR intervention, not only the effectiveness.

2.2 Instruments

2.2.1 IVR tool

The EONXR platform was used to carry out the lecture in IVR. It already has several lectures that can be used in IVR mode. The teacher can carry out the lecture using these materials in desktop mode, through a PC, or in HMD mode. In the meantime, students can use HMD to explore virtual reality and interact with it based on the teacher's instructions.

In this study, based on the school curriculum, it was decided to carry out the activity within the science class. The topic chosen was that of volcanoes. During the explanation, the students had the opportunity to decompose the whole image of the volcano to understand the names of the structures of which it is composed (Fig. 1). Each student was provided with a Virtual Reality Glasses Bercley ITEM 5244 cardboard. The subjects could view the virtual contents by inserting a mobile phone with the EONXR application installed into the cardboard.

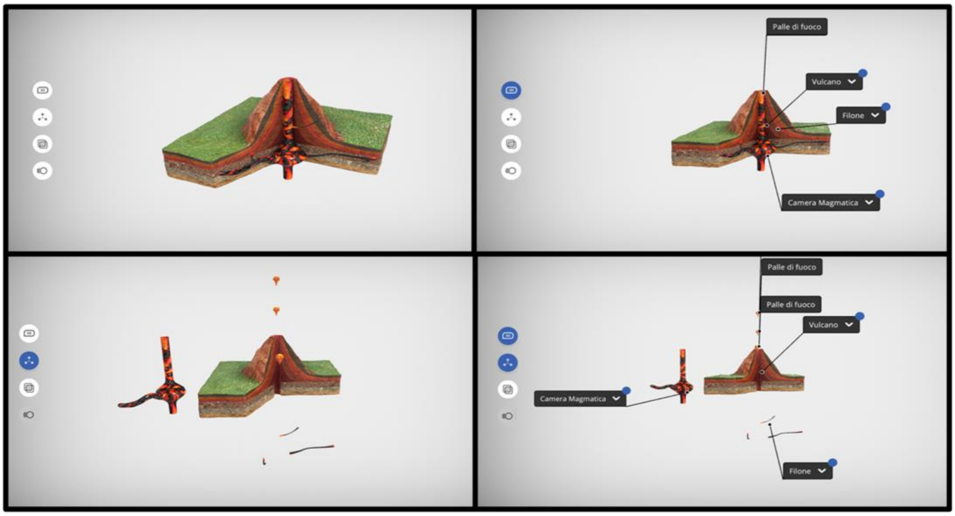

Figure 1: Screenshots of the application EONXR. The 4 possibilities viewable by the subjects are shown: the whole image of the volcano, the illustration of the names of the main components, the figure's breakdown, and the figure's breakdown with the components' terms.

2.2.2 Previous IVR knowledges questionnaire

Before starting the experimentation, all 34 students completed a questionnaire to evaluate the degree of knowledge of the IVR, their previous experiences with this new technology and the contexts in which it was used. The questionnaire consists of three questions. The first, with a dichotomous response, investigates whether the students have ever had experience with IVR. The second, open-ended asks students about the contexts and situations in which they have had the opportunity to experience the IVR. The third, a question in a 4-degree Likert scale format (from 1=never to 4=more than 10 times), investigates the number of times subjects used the IVR.

These variables assume considerable importance because they allow us to understand whether the novelty effects of IVR technology interfere with other results obtained in this study.

2.2.3 Presence and sickness questionnaire

To measure students' perception of presence, previous studies have used the Igroup Presence Questionnaire (IPQ). It consists of 14 items divided into three scales (spatial presence [5 items], involvement [4 items], experienced realism [4 items]), plus an item that synthetically detects the presence (Schubert, Friedmann, & Regenbrecht, 2001). As regards the forms of malaise and adverse sensations encountered by the sample during the use of the devices, the Virtual Reality Neuroscience Questionnaire (VRISE) was examined (Kourtesis, Collina, Doumas, & al, 2019). It is composed of four scales for a total of 20 items: user experience (5 items), game mechanics (5 items), in-game assistance (5 items), VR Induced Symptoms and Effects (5 items). After being translated for this research, the IPQ was administered in its original version. Each item was rated on a 5-point Likert scale (from 1, strongly disagree to 5, strongly agree). Of the VRISE, only the VR Induced Symptoms and Effects scale was used to measure discomfort or negative sensations experienced during the VR activity to not burden the students' cognitive load too much at the end of the lecture. The scale comprises 5 items measured on a 7-point Likert scale (from 1, extremely intense to 7, absent).

2.2.4 Learning assessment test

All students completed a pre-test, built in collaboration with the teacher, consisting of 10 multiple-choice questions (with four choice options) concerning the contents of the subject of experimentation (volcanoes) to measure prior learning.

The post-test consisted of the same questions as the pre-test. The teacher wanted to add another ten questions concerning specific contents covered during the lecture but not related to the teaching experience with the IVR.

2.2.5 Coding scheme

Three action cameras were positioned inside the classroom to understand how the students interacted in real space during the IVR activity. Based on the elements that emerged from the literature and a preliminary view of the video recordings made, a coding scheme was developed which envisaged four macro areas of analysis: the movement difficulties of the subjects caused by the architectural structure; those caused by the classroom furnishings; those caused by the position of the classmate (peripersonal space) (Cardinali, Brozzoli, & Farnè, 2009); the unnatural movement of the students[3].

2.3 Procedures and data collection

The science teacher managed the teaching activity and was structured over 3 sessions held on different days in February 2022.

During the first two sessions, only the subjects belonging to the experimental group were involved in carrying out two technical tests relating to the use of hardware and software. The two tests were one hour each, during which the students tested the cardboard and the functioning of the EONXR application on their smartphones

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[3] The expression "peripersonal space" means the space consisting of «a region immediately surrounding the body, characterized by a high degree of multisensory integration between visual, tactile and auditory information, which differs from the more distant regions of space» (Cardinali, Brozzoli, & Farnè, 2009).

and viewed some test lectures already present within the platform. During the third session, both groups were involved but on different days.

After completing the questionnaire concerning the general knowledge of the IVR and having carried out the pre-test, the two groups participated in the lecture on volcanoes. The control group followed the lecture traditionally, through the textbook; the experimental group participated in the lecture with IVR activity using cardboard (Fig. 2). The IVR activity was recorded using three video cameras.

The lecture lasted a total of 55 minutes. Within this period, the activity in IVR mode lasted approximately 10 minutes. The teacher introduced the topic through traditional teaching methods (textbook) and invited the students to take their IVR devices.

The teacher explained the IVR contents using the platform's desktop mode using the viewer. The teacher's choice not to wear the visor because she did not want to lose control of the class and because she preferred to pay more attention to the explanation to be carried out without the involvement given by the visor. This choice did not alter the research situation.

At the end of the lecture, all the students took the post-test; the control group also completed the questionnaire consisting of the four IPQ scales to detect the perception of presence and a VRISE scale to detect the perception of presence and the discomfort experienced during the IVR activity..

At the end of the lecture, all the students took the post-test; the control group also completed the questionnaire consisting of the four IPQ scales to detect the perception of presence and a VRISE scale to detect the perception of presence the discomfort experienced during the IVR activity.

Figure 2: Experimental group during the IVR lecture in the school classroom

2.4 Data analysis

The data collected with the questionnaires (previous experience of IVR, IPQ, VRISE) and the learning tests were entered into an SPSS 20 dataset and subjected to descriptive statistical and central tendency analyses.

Before calculating the scores of the scales relating to the perception of presence and discomfort and comparing the pre-test and post-test scores, we subjected the individual items to a check of the normal distribution of values with the non-parametric test of Kolmogorov- Smirnova. Furthermore, in the case of some items on the iPQ Experienced realism scale, their semantic polarity was reversed.

The scores on the scales relating to presence and discomfort were also subjected to a measure of reliability (Cronbach's alpha).

To compare the pre-test and post-test results, the non-parametric Mann-Whitney U test was performed, considering a significance level of $p < .05$. The comparison took place only on the 10 items in common between the two tests, i.e. those directly relating to the contents concerning the IVR experience.

We also used student’s t-test to verify if having previously had an experience with IVR could have influenced the results of the IPQ scales and the perception of malaise.

The video recordings were subjected to a content analysis using NVivo 12 based on four categories (interference with furniture; interference with architectural structure; invasion of peripersonal space; students' unnatural postures) to understand whether the conformation of the environment or the position of the students caused an impediment in the movements of the subjects for the success of the teaching activity in IVR mode.

3. Results

The results have been grouped according to the research questions to facilitate the presentation.

3.1 Previous IVR knowledge and use contexts

Regarding previous experiences with IVR, 50% of the students in the experimental group and 80% of the control group stated that they had never had any experience with IVR beyond what was done in class. The two groups have no statistically significant differences (χ^2 =3,044; p=.085).

Have you had virtual reality experiences in addition to those done at school?	Control Group	Experimental Group	Total
No	12	8	20
Yes	3	8	11
Total	*15*	*16*	*31*

Table 1 - The students' previous IVR experiences

The primary contexts of IVR use concern museums and activities with friends. In only two cases is it claimed to have used it during the previous school career. It also emerges that of the 11 students who used the IVR, 9 said they did it less than 5 times.

3.2 Perception of presence and sickness

As regards the IPQ items, for all items – except item 4 (I did not feel present inside the virtual space) relating to the scale of spatial presence) – it was possible to accept the null hypothesis (Gaussian distribution). For this reason, item 4 was excluded from subsequent processing.
Concerning the Induced Symptoms and Effects scale of the VRISE questionnaire, in four cases out of 5 it was possible to accept the null hypothesis: item 5 (During the experience, did you have a feeling of instability?) was excluded from subsequent elaborations.
The perception of students' presence during the IVR experience was measured using the three IPQ scales. The data in Table 2 show that, to some extent, the students had, on average, a strong sense of physical presence (M=3.40, SD=0.78). Still, they perceived a lower general involvement (M=2, 81, SD=0.81) and a lower sense of realism (M=2.87, SD=0.72) about the interaction with the decomposable image of the volcano. The mean value of the item that measured the general perception of presence (item 1) is 3.41 (SD=0.62).

Scale	Mean	SD	α
Spatial presence (4 item)	3,40	,78	.79
Involvement (4 item)	2,81	,81	.63
Experienced realism (4 item)	2,87	,72	.83
General presence perception (1 item)	3,41	,62	--

(N=17)

Table 2 - The students' scores on three IPQ scales and Cronbach's alpha value

The perception of sickness measured with the VRISE Induced Symptoms and Effects scale (α = .92) during the IVR activity declared by the students was, on average, low (M=2.72, SD=1.45) but with high variability. In this regard, it should be noted that in 4 cases out of 17, the average value of discomfort is greater than 5 out of a maximum value of 7.
We also analyzed Student's t to verify if having previously had an experience with IVR could have influenced the results of the IPQ scales and the perception of malaise. All Student's t values were associated with a p-value > 0.05. So the perception of presence and discomfort is independent of having or not having a previous IVR experience.

3.3 Difference in the learning achievements between the experimental and control groups

The results concerning the learning levels were measured by comparing the results obtained in the pre-test by the experimental and control groups and, subsequently, by comparing the post-test results abetween the two groups.

The post-test score distributions were found to have a non-normal trend (Kolmogorov-Smirnov test with $p<.05$) for both the control and experimental groups. In addition, the post-test score distribution of the control group had multiple outliers. For this reason, the Mann-Whytney U nonparametric statistical test for independent samples was used to calculate the difference between the learning test scores (Table 3). The result of the analysis led to accepting the null hypothesis: the mean rank score in both the control and experimental groups of the pre-test and post-test is not different in a statistically significant way ($p >.05$).

Test	Group	N.	Mean rank on categories of group	Rank sum	Mann-Whitney U	Sig. (p value)
Pre-test	Control	17	18,65	317,00	125,000	,518
	Experimental	17	16,35	278,00		
Post-test	Control	17	20,74	352,50	89,500	,057
	Experimental	17	14,26	242,50		

Table 3 - Hypothesis test summary of the pre-test and post-test based on the groups

3.4 Relationship between the movements of the subjects and the structuring of the real space of experience

As regards the detection of the influence of the physical space and of the furnishings placed in the environment in which the IVR experience took place, as well as of the student's behavioural interactions, the results were obtained from the thematic analysis of video recordings made with the use of NVivo 12 qualitative analysis software (Edhlund & McDougall, 2010). During the ten minutes of activity with the viewer, 3 interferences with architectural structure (Fig. 3) and 2 invasions of peripersonal space were found (Fig. 4).
A relevant result concerns students' unnatural postures while using the IVR inside the classroom. About 15 times, during the ten minutes of experience with the viewer, the students positioned themselves, for example, with their backs to the

desk or their heads were thrown back. In both cases, we deal with unnatural postures for a didactic activity in a school classroom.

Figure 3: a case of interference with the architectural structure

Figure 4: a case of invasion of peripersonal space

Discussion

The data were collected to obtain some initial results of the use of IVR in the Italian school context to design future research. As a premise, it should be restated that the research was conducted with an exploratory perspective. Furthermore, the intrinsic limitations of the research connected to the influence of the novelty effect of the IVR on students and the limited duration of the IVR experience as well as the type of experience must be kept in mind.

Regarding the first objective of the research (previous knowledge of IVR and contexts of use), the results reveal that a small number of students had already used IVR previously and almost never in school. It can therefore be seen that IVR is an expanding technology but still not very widespread among school students today. 65% of the students involved had no previous experience using the IVR, and the uses found showed that only 6% were concerned with the school context. This data type has not been investigated in previous research in the school context. However, it provides elements to support the need of preparatory moments for the use of IVR in school contexts. Furthermore, although research (Cheng & Tsai, 2019; Shi et al., 2019) has shown a growing interest in the possible use of these technologies in educational contexts, the data collected invites us to pay close attention to the novelty effect, especially in the prospect of including IVR in daily teaching practice.

Regarding the second objective (detect the perception of presence), the data reveal that the majority of students perceived themselves as physically present within the experience but felt less involved and perceived a lower sense of realism. These results are in line with the work of Shi et al. (2019) and Cheng et al. (2019), although the type of experience with IVR is very different: in the first case, the vision was performed independently by the students; in the second case, as in ours, the experience with the IVR was accompanied by the simultaneous explanation by the teacher who guided the vision. Indeed, this aspect will have to be further investigated with qualitative approaches to understand more deeply this dimension of the phenomenon.

Regarding the forms of sickness, we recorded a low general perception of discomfort following the use of the IVR, despite some cases (about 20%) reporting a non-negligible malaise. This aspect also seems not to have been investigated in school research. However, even considering the biases in students' responses, the data confirm those found in other studies developed in different contexts (e.g., Chang, Kim, & Yoo, 2020). However, these results need to be taken into account, especially with regard to the dissemination of IVR in school settings.

Considering the fourth objective (difference in the learning level between the experimental and control groups), there were no statistically significant differences in learning outcomes. These findings do not align with what has been reported in other studies (e.g., Villena Taranilla et al., 2019; Bhattacharjee et al., 2018; Shi et al., 2019). Certainly, the brevity of the experience, how the teaching activity was managed by the teacher and the type of material used had a significant influence.

Finally, considering the last objective of this work (the relationship between the movements of the students and the classroom space), there were no substantial interferences between the students or between them and the architectural structure that could preclude a fair use of the IVR in the classroom. However, we have observed a non-negligible number of unnatural postures assumed by the students during the experience. This dimension of the didactic activity necessarily needs further future developments.

Conclusion

In conclusion, it is essential to highlight some limitations of our research. First of all, an analysis of the motivational aspect of the subjects was not carried out after performing the experience through the innovative technological device since the brevity of the experience did not seem to justify its detection. Secondly, the analysis of the learning outcomes was carried out with the purpose of collecting initial orientation information. It would have been necessary to redesign the teaching activity differently than in the traditional organization and provide a more extended educational intervention to investigate this aspect in depth. It was impossible to satisfy this condition as the equipment used did not allow prolonged use. Furthermore, from the thematic analysis of the video recordings and the investigation concerning the relationship between student-space configuration and student-student, we have found the importance of paying attention to the student itself, individually, and to the student-teacher interaction.

Despite these limitations, we believe that the results of this study can provide points of attention for the design of further research activities in the educational field with the use of IVR and the involvement of all subjects simultaneously within a classroom. In particular, we believe it is appropriate to investigate the previous experiences of students and teachers with IVR; to detect, with qualitative approaches, the perceptions of students' presence and discomfort and the teaching strategies used by the teacher to design interventions in the classroom; use learning assessment devices that better guarantee didactic validity; to detect, from an ergonomic perspective, classroom behaviour of students and teachers involved in teaching activities.

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