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Esperienze, strumenti e ambienti per la didattica immersiva

Testing innovative preparation tools for immersive virtual environments. A case study in the didactics of Art

Sperimentazione di strumenti di preparazione innovativi per ambienti virtuali immersivi. Un caso di studio nella didattica dell'Arte

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Abstract

In recent years, the usage of immersive media and Virtual Reality (VR) has become widespread in the education field. VR has been claimed to offer significant benefits in terms of motivation, engagement, and learning outcomes in various disciplines. In this research, we aim to assess the potential of VR in improving the way university students engage with VR art in the classroom. More specifically, we focus on how this technology can be used to provide preliminary knowledge and training for experiencing immersive art, and how this impacts on the students' level of satisfaction, immersion, and engagement. Our results contribute to advancing the scientific debate on the usage of VR in the education field; additionally, they may be useful to artists and curators, by suggesting an innovative way of introducing the users to immersive artworks.

Sintesi

L'utilizzo dei media immersivi e delle tecnologie di realtà virtuale (VR) rappresenta un campo in rapida espansione, soprattutto per i benefici dimostrati in termini di motivazione, *engagement* e apprendimento. Alla luce di questo, la ricerca mira primariamente a indagare il potenziale della VR nella didattica universitaria, cercando di comprendere come tale tecnologia possa essere utilizzata per fornire informazioni preliminari e competenze operative utili alla fruizione di opere d'arte immersive e come questo influisca sui livelli di soddisfazione, immersione e coinvolgimento degli studenti. I risultati ottenuti apportano un contributo al dibattito scientifico rispetto all'impiego della VR in ambito didattico e possono essere utili ad artisti e curatori nel suggerire modalità innovative di avvicinamento alle opere artistiche.

KEYWORDS: virtual reality, immersive didactics, art, anticipation, higher education

PAROLE CHIAVE: realtà virtuale, didattica immersive, arte, anticipazione, educazione universitaria

[1] The authors designed the present study together and they agree on the structure and content of this paper. Federica Cavaletti wrote paragraphs Introduction, 1, and Conclusions. Ilaria Terrenghi wrote paragraphs 2 and 3. Paragraph 4 was written collaboratively.

Introduction

Virtual reality (VR) is a media technology that delivers immersive and often interactive content to the users either by means of headsets or, less frequently, projection systems like the CAVE. One of the novelties of VR compared to previous audiovisual media consists in its capacity to elicit two strong illusions: place illusion, and plausibility illusion (Slater, 2009). The former indicates the feeling of actually "being there" (i.e., in the virtual environment) and gives rise to what is called a sense of presence; while the latter type of illusion refers to the feeling that the events in the virtual environment are really taking place. These forms of perceptual illusion are resistant to cognition: that is, they are experienced even though VR users are normally aware that their senses are being "tricked" (Freina & Ott, 2015; Servotte et al., 2020).

With technological advancement, it is becoming increasingly easy to create detailed scenarios in which the users can be immersed realistically. In addition to offering new opportunities in the domain of entertainment (Pallavicini et al., 2019), this has paved the way for innovative applications of VR in multiple professional domains as well. One of them is education (Hamilton et al., 2021; Checa & Bustillo, 2019).

The implementation of technology-aided education as a pedagogical and didactic method is not a recent phenomenon, and studies assessing its efficacy have been carried out for almost half a century. As far back as the 70s, Ellinger and Frankland (1976) found evidence that using early computers to teach economic principles produced comparable learning outcomes than traditional didactic methods. Nowadays, even though the research on learning outcomes, intervention characteristics, design, and assessment measures associated with VR usage has been somehow unsystematic, the adoption of this technology as a pedagogical method is considered promising and appears to be useful and effective (Jensen & Konradsen, 2018; Jang, 2008; Nurbekova et al., 2022).

VR efficiently supports all three scenarios that neurodidactics has shown to be connected with the learning process, i.e., modeling, repetition, and experience (Terrenghi & Garavaglia, 2022). In addition, it affords two medium-specific possibilities that are particularly relevant in view of educational purposes: creating compelling but safe environments, and allowing 3D and manipulable visualizations of otherwise hard-to-access content. The former is useful for those situations in which learning requires practicing repeatedly complex or dangerous tasks. In this area, education blends with training.

For instance, Sankaranarayanan and colleagues (2018) demonstrated the effectiveness of a VR-based training simulation system for teaching medical residents how to manage fire in the operation room. VR visualizations, on the other hand, are useful to gain knowledge or skills concerning content that is normally inaccessible. To support biological studies, Zhang and colleagues (2019) developed BioVR, an interactive and immersive VR system for visual analysis of DNA, RNA, and protein sequences and structures. In a different field, Vegetti (2022) used VR for teaching students in architecture and interior design spatial and perceptual concepts that would be too abstract to be grasped theoretically. Sometimes, cognitive and procedural learning are combined. Pirola and colleagues (2020), for instance, regularly employ in classrooms a virtual rendering of a chemical plant: students can familiarize with its physical structure, but also try out operations to test its dynamic behavior.

One limitation in the current usage of VR for educational purposes is that, up to now, it has been typically limited to a reduced number of disciplines: mostly hard and biological sciences, and sometimes engineering and architecture (Hamilton et al., 2021). Less effort has been put in the domains of the humanities, especially in the arts.

At the same time, VR has become a new tool in the arts themselves. The introduction at the Venice International Film Festival of a VR section in 2017 and the works presented in multiple contexts by celebrated artists as Jon Rafman, Jordan Wolfson, Cao Fei, Olafur Eliasson, and Marina Abramovič attest to the fact that VR has become an autonomous medium for artistic expression.

Art teaching normally involves direct exposure to the works to be studied, or at least their reproduction. As VR works are hardly reproducible with traditional techniques, they can only be experienced properly by using adequate headsets and controllers. Therefore, with these works likely being included in the upcoming teaching programs, it is reasonable to expect that VR will become a necessary educational tool in the field of Art education.

However, this technology can often be unfamiliar and thus challenging for the average users, a limitation that is explicitly acknowledged in the literature (e.g., Checa & Bustillo, 2019). One important dimension in this regard is control, i.e., the degree to which one feels that they can use the equipment to perform the desired actions in the virtual environment.

Control is a key dimension of presence in VR according to Witmer and Singer's conceptualization (1998), and in the related field of game studies it is deemed crucial for involvement as well, particularly in its kinetic component (Calleja, 2011). Conversely, a lack of control is likely to affect the users' experience detrimentally.

Therefore, the experience of VR art may be enhanced by offering preparation sessions using this very technology – a practice that is not yet established in Art teaching. Considering the main evidence in the educational and didactic field, proper preparation has been shown to positively affect the learning process.

The preparatory moment is a phase in which teachers can: share with the class specific aspects of the learning path (e.g., anticipating didactic steps, topics, objectives, future activities, evaluation criteria, etc.); design significant occasions for a first approach to knowledge; propose some exploratory or informative activities, aimed at introducing the students to the field or the learning object. For instance, the Flipped Classroom methodology (Mazur, 1991) and the Episodes of Situated Learning (EAS) methodology (Rivoltella, 2013) propose in their structure a moment in which students have to actively explore a didactic object or a general topic, before working on it at school. In the case of the EAS methodology, Terrenghi and colleagues (2019) demonstrated that this didactic approach is effective in terms of students' engagement (Fredricks et al., 2004), and has a positive impact on perceived emotions in the classroom.

We also know that a well-designed anticipatory moment can be helpful for students to better understand the meanings and the features of the learning experience. Furthermore, it can be a crucial access-point in order to activate students in the following exploration of the learning objects (Gardner, 1999). Some recent studies (e.g., Ferrari & Terrenghi, 2021) show that anticipating information about something that has to be learned enhances engagement and motivation, improves the understanding of theoretical elements, and, moreover, helps to focus on details that would have been left out otherwise.

To sum up, since research has indicated VR as a promising didactic tool, we believe that its usage could be extended to disciplinary fields in which it is not yet established. As VR is being increasingly employed as an artistic medium, this technology could be first and foremost adopted in Art programs including VR artworks. More in particular, given the demonstrated importance of preparatory procedures in the learning process, we believe that it could be used to provide immersive preparatory moments that could be beneficial in relation to the fruition of given artworks, allowing the user to approach it in an aware and informed way.

1. Research questions

Based on the premises above, we set to explore the potential of medium-specific preparation to VR artworks compared to different media alternatives. In order to do so, we identified a VR artwork that featured original VR-based preparation materials that we could both use in unedited form and turn into printed materials.

The chosen VR artwork was "Rosetta Mission 2020" (Figures 1 and 2), created by Italian artist Luca Pozzi, and curated by Elisabetta Modena and Sofia Pirandello, in collaboration with Swan Station (2021)[2]. The artwork features a comet floating in space that the users are invited to reach after transforming themselves into particles (quarks, protons, and so on).

Once at destination, users can explore five areas of the comet, hosting contributions by as many artists or scientists: Luca Pozzi himself, Carlo Rovelli (theoretical physicist), Alain Connes (mathematician), Michelangelo Pistoletto (artist), and Garret Lisi (physicist).

[2] Produced by ERC Advanced Grant: "AN-ICON. An-Iconology: History, Theory, and Practices of Environmental Images".

FIGURE 1 - LUCA POZZI, "ROSETTA MISSION 2020" (67P CHURYUMOV-GERASIMENKO'S COMET GLOBAL VIEW). SCREENSHOT FROM VR GAME ENGINE UNITY IN 4K

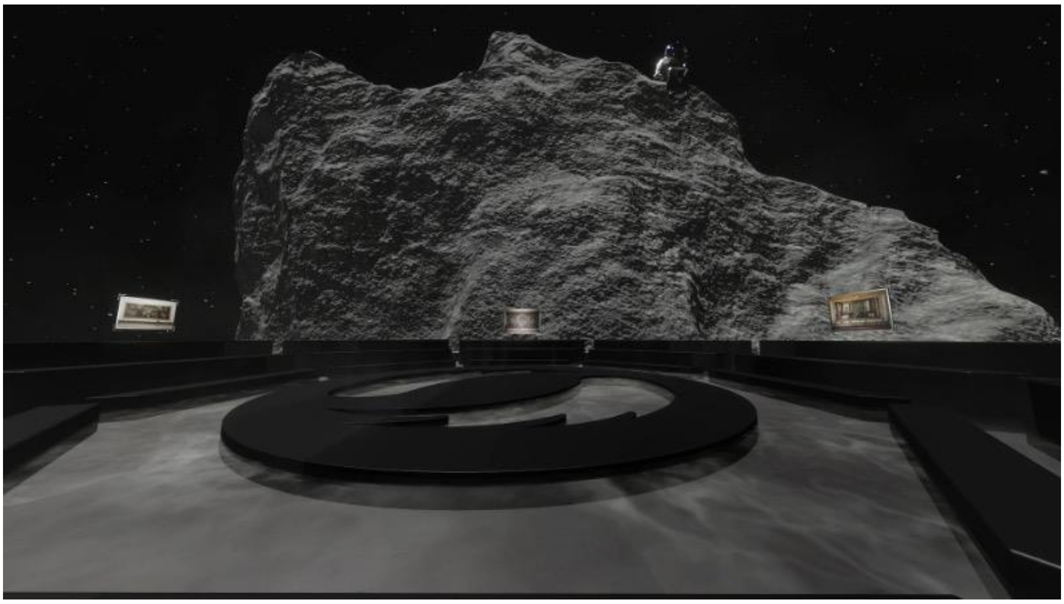

FIGURE 2 - LUCA POZZI, "ROSETTA MISSION 2020" (67P/CHURYUMOV-GERASIMENKO'S COMET MAIN CANYON DETAIL/SWAN STATION). SCREENSHOT FROM VR GAME ENGINE UNITY IN 4K

What was relevant to us is that the described VR artwork is set within a VR replica of *Casa degli Artisti*, an actual exhibition space in Milan in which Pozzi was hosted as artist-in-residence when working on this project. The virtual exhibition space comprises preparatory materials that the users go through before starting the Rosetta experience. Therefore, in the original set up, users have a VR-based introduction to a VR artwork.

For the purposes of our study, as described in more detail in the methodology section, we created a printed version of the original VR introduction to the artwork, to be consulted like a regular leaflet. This allowed us to obtain two alternative experimental conditions: preparation with VR, and "pen-and-paper".

In light of the theoretical background and empirical evidence summarized above, we formulated the following hypotheses:

- 1a – Preparation with VR will increase the students' mastery of the preliminary knowledge required to understand the chosen work of art – compared to pen-and-paper preparation;
- 1b – Preparation with VR will increase the students' sense of control on the technology – compared to pen-and-paper preparation;
- 2 – Increased mastery and increased control will make the students more satisfied with the experience of the chosen work of art – compared to pen-and-paper preparation.

We tested these hypotheses with a pilot study aimed at assessing the feasibility of the research process, and possibly to replicate the study in the future with an increased sample. This first study took place within the framework of the laboratory "Immersive stories and memories. From virtual arts to video games", held by professor Elisabetta Modena, and proposed to the students of the Master Degree in Philosophy of the University of Milan (academic year 2022/2023). The choice of this laboratory was supported by the fact that it adopted an immersive methodology, coherent with our research objectives; for this reason, the educational syllabus was not changed. Additionally, our pilot study received a formal approval from the Ethics Committee of the University of Milan (protocol n. 105/22, 5th December 2022).

2. Methodology

We implemented a mixed method approach (Creswell et al., 2003; Creswell & Creswell, 2018), including the collection, analysis, and combination of quantitative and qualitative data in the same study.

This is because we believe this kind of approach can offer a more holistic understanding of the learning processes we studied and is well suited to dealing with their complexity. In particular, we applied a dominant embedded design (Creswell & Plano Clark, 2007): we worked with one dominant type of quantitative data, collected through questionnaires, and then we obtained qualitative data as a secondary support.

These additional data, collected through interviews, complemented our primary data set. This methodological solution has two main advantages: on the one hand, it allows for the construction of a solid and complete dataset within which selected topics can be examined more in detail; on the other hand, it leaves data interpretation to the end of the collection and processing phases, allowing less biased understanding.

2.1. Research design

Participants were recruited among the students taking part in the above-mentioned laboratory "Immersive stories and memories". All students were offered the opportunity to enroll in the study on a voluntary basis, being assured that their decision would not have any consequences on their final laboratory evaluation. Information sheets presenting the general framework of the study and the terms of participation in the research were distributed in the classroom. 17 students decided to participate in the research and provided their informed consent; 5 of them later withdrew. Therefore, our final sample consisted of 12 students (10 males and 2 females; average age: 38). 9 out of 12 students declared they had at least one immersive experience with VR headset and controllers. Most participants had never visited any online virtual world (10 out of 12) nor any immersive exhibition (9 out of 12).

The experimental design comprised two main data collection sessions: one at week 0 (pre-experience phase) and another one at week 1 (post-experience phase).

The first phase was dedicated to gathering preliminary information allowing to divide the sample into two groups with comparable familiarity with immersive media, and it relied on the "Pre-experience questionnaire" (see 2.2.). Based on the obtained results, we created two groups composed of 6 participants each. The majority of the participants were university students aged 22–25; 2 outliers aged 64 and 65 respectively were assigned each to one group.

One week after the first phase, we ran the experiment proper. Participants were instructed to join the group they had been assigned: virtual reality (VR), or pen-and-paper (P&P). The two groups were placed into two separate and quiet rooms. In both conditions, participants were provided preparatory materials concerning the VR artwork *Rosetta Mission 2020* by Luca Pozzi and then experienced the artwork itself.

While the preparatory phase was conducted autonomously by the participants (with 4 research assistants monitoring and intervening only to fix possible technical issues), the artwork phase was guided by professor Modena in the role of a museum guide.

After completing the artwork phase, all participants – regardless of their condition – were invited to fill in three post-experience questionnaires. Before leaving, participants were informed that, on a voluntary basis, they could decide to enroll in an additional phase of the experiment (week 3) in which they would undergo unstructured interviews concerning specific aspects of their experience. 3 participants took part in this phase.

2.2. Instruments and materials

The quantitative data were collected through four questionnaires. The first of them was administered before the participants underwent the VR experience; the second, third, and fourth afterward.

The “Pre-experience Questionnaire” was created *ad hoc* in order to obtain information from the participants, allowing to create homogeneous and comparable experimental groups. Indeed, our study design involved contrasting two conditions (VR-based and paper-based preparation), which required splitting the sample into as many groups. This first questionnaire included 5 open-ended profiling questions and 18 additional open-ended questions aimed at exploring the participants’ previous experiences linked to VR, video gaming, and virtual worlds (e.g., Second Life). Possible past stressful episodes connected with these technologies or media were inquired as well.

The “Preparatory Moment Questionnaire” was the first post-experience questionnaire we administered. It aimed at capturing the students’ evaluation of the perceived impact of the preparatory moment on the learning processes. It was composed of 12 statements that had to be rated on a 7-point Likert scale. Each statement was based on the circular model proposed by Schwartz and Hartman (2007), which describes learning outcomes connected to four different actions: to see (the student perceives information and details, e.g., “The preparatory moment allowed me to collect useful information for the experience”); to say (the student can explain a fact, e.g., “The preparatory moment allowed me to better understand the general meaning of the experience”); to do (the student develops attitudes or skills, e.g., “The preparatory moment helped me to foresee some elements of the experience”); to motivate (the student is engaged and experiences high levels of interest, e.g., “The preparatory moment allowed me to apprize the experience”).

The “Engagement Questionnaire” was the second post-experience questionnaire we administered. It included 7 open-ended questions created *ad hoc* in order to collect the students’ statements about their perceived learning outcomes and their interactions during both the preparatory moment and the immersive experience; it also included a validated battery from the literature (Georgiou & Kyza, 2017) aimed at exploring the students’ level of engagement. This second part proposed 15 items, such as “I was curious about how the activity would progress” or “I often felt suspense by the activity”, to be rated on a 7-point Likert scale.

The “Presence Questionnaire” was the third post-experience questionnaire we administered. It is a validated instrument completely based on the study of Witmer and Singer (1998). We choose 14 items from the original instrument, following the criterion of coherence (the questions had to suit the immersive experience we proposed) and representativeness of the categories (we chose questions from each of the four subscales of the original questionnaire). Each item was to be rated on a 7-point Likert scale.

All the questionnaires were imported into Microsoft Forms and shared with the students via a link that led to the page where they could be filled out. Each questionnaire was pseudonymized.

As for the qualitative data, they were collected through unstructured interviews. The participants were given the possibility to contact the researchers to deepen any elements of the experience that they perceived as significant. Depending on the availability of the students, the interviews were run either face-to-face or online, using Microsoft Teams (which is the communication platform formally adopted by the University).

Interviews had more than one purpose: on the one hand, as we mentioned above, they aimed at collecting supplemental data in order to better interpret data from questionnaires; on the other hand, they offered a relevant occasion to bring out perceived weaknesses of the overall organization of the trial. On this grounding, the draft of the interview proposed only one opening question, asking the participants to recall and describe the immersive experience they lived. The following excerpt exemplifies a typical incipit: "The immersive experience on the *Rosetta Mission* happened some days ago; so, if you want to, take some time to go back with your mind to the moment in which you entered the space, and you started your experience on the comet. Take the time that you need to recall this experience. Once you have the start of the experience clear in your mind, you can start telling me what happened". The interview then continued with the request to focus on and deepen some of the details that the interviewee would mention.

The preparatory materials comprised: an abstract of the artwork concept; 5 panels with texts and images illustrating the main features of the 5 areas of the comet (Figures 3 and 4); a map showing the locations of these areas; and instructions for choosing an avatar and starting the space travel towards the comet. The difference between the two conditions consisted in the fact that the VR group accessed these materials in the form of virtual content located in the same virtual space where the artwork experience would start later on; therefore, participants in the VR group wore their headsets at the beginning of the preparatory phase and proceeded directly to the artwork phase. Instead, the P&P group received the same materials (both texts and visuals) in the form of a printed information sheet – resembling the leaflet one would commonly find in a museum; therefore, participants in the P&P group only wore their headset when starting the artwork experience.

FIGURE 3 – THE PREPARATORY MATERIALS AS THEY APPEAR IN THE ORIGINAL VR ENVIRONMENT (TWO PANELS, SCREENSHOT)

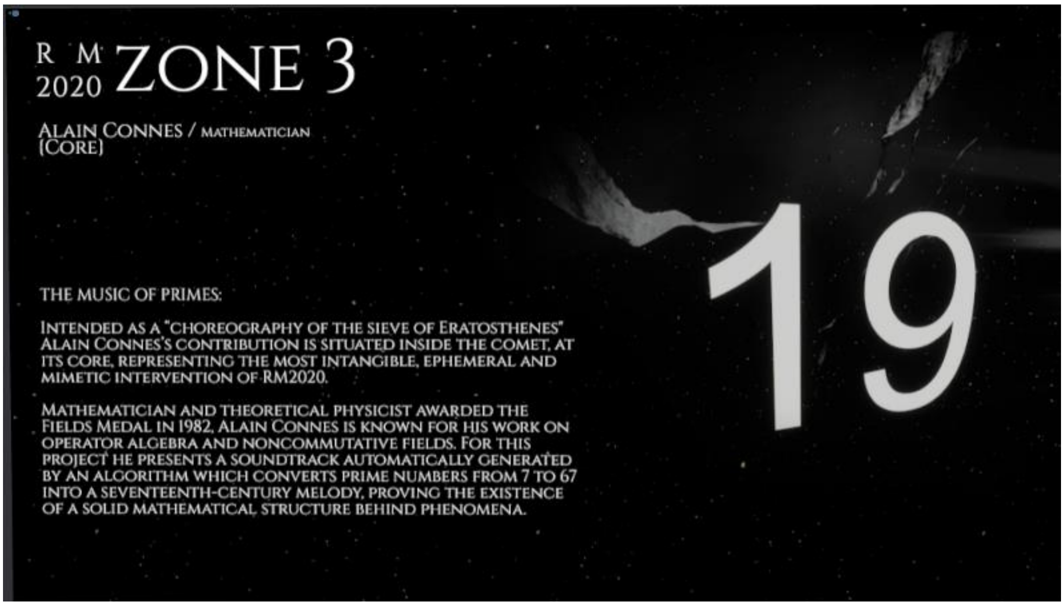

FIGURE 4 – THE PREPARATORY MATERIALS AS RENDERED IN THEIR PAPER-BASED FORM (ONE PANEL)

3. Results

In this section, we present the main results emerged from the descriptive analysis of the three post-experience questionnaires, which obtained 12 sets of responses each. Our primary purpose is to explore the students' perceptions of the immersive experience and highlight the main differences between the VR group and the P&P group, trying to understand the potential of an immersive anticipating moment.

The Preparatory Moment Questionnaire asked the students to rate 12 didactic outcomes statements on a 7-point Likert scale (Figure 5).

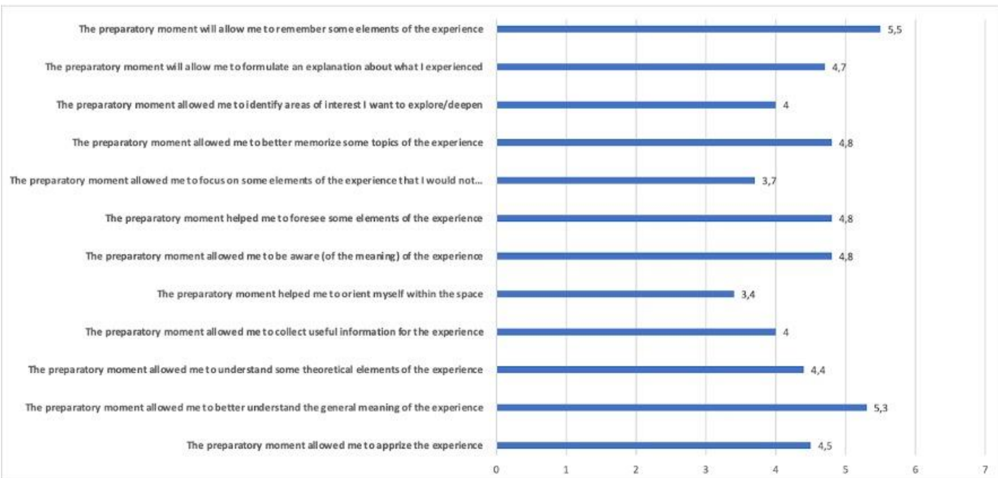

FIGURE 5 – RESULTS FROM THE PREPARATORY MOMENT QUESTIONNAIRE – TOTAL AVERAGE VR + P&P

Considering the overall results, 2 items indicating the perceived didactic outcomes scored more than 5 average points: the first one concerns the comprehension of the general meaning of the immersive experience (M = 5.3), and the second one the students' ability to remember some elements they observed during the immersive exploration of the comet (M = 5.5). It is interesting to notice the difference in distribution of the two groups of participants as well (Figure 6).

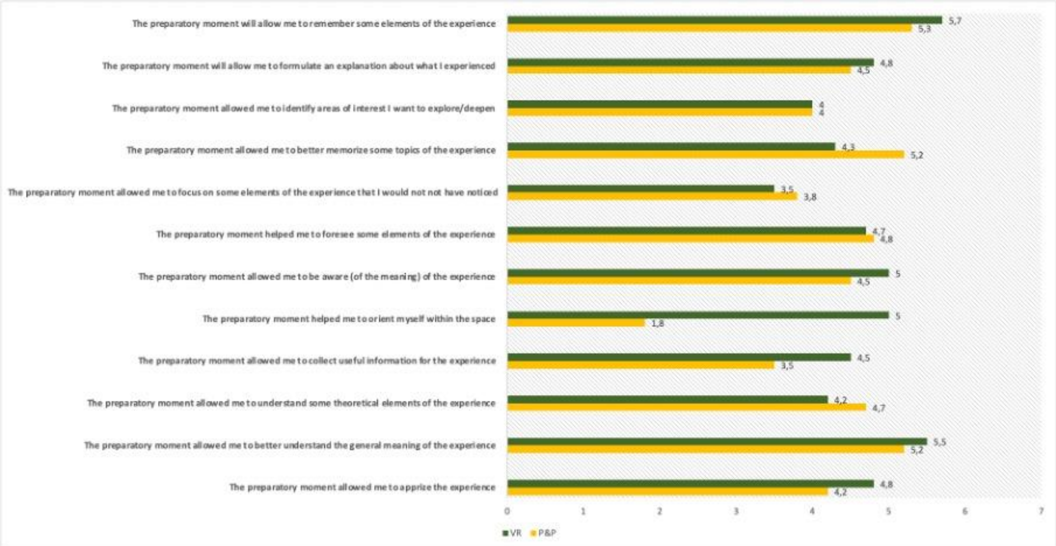

FIGURE 6 – RESULTS FROM THE PREPARATORY MOMENT QUESTIONNAIRE – AVERAGE FOR VR GROUP AND P&P GROUP RESPECTIVELY

Figure 6 shows a very different distribution between the two groups of participants. Concerning some specific items, it is possible to notice that the VR group and P&P group differ by more than 0.5 mean points.

Regarding the former group, the participants declared that the immersive preparatory moment helped them to orient within the space (+3.2 average points compared to P&P group), to collect useful information about the experience (+1 average point), and to appraise the experience (+0.6 average point).

On the contrary, the participants of P&P group claimed to have appreciated the preparatory moment especially because it helped them to better memorize some topics of the experience (+1.1 average point compared to VR group), and to understand some theoretical elements too (+0.5 average point).

The Engagement Questionnaire addressed the students' interactions during both the preparatory moment and the immersive experience, the elements that students thought they learnt, and their level of engagement in stricter sense.

Regarding the first topic, results show that students interacted few times (3 times during the preparatory moment and 4 times during the immersive visit on the comet) and only to joke with other classmates.

Then, the questionnaire asked the students which parts of the experience particularly struck them ("Think about your virtual experience on the comet. What are the most relevant elements you learnt?").

Students could respond by choosing multiple answers, and they mainly indicated the artworks they saw ("The artworks I observed on the surface of the comet", n. 11 occurrences); the comet itself ("The structure and shape of the comet", n. 9 occurrences) and, finally, the artists' message ("The meaning of the artworks", n. 3 occurrences).

Regarding engagement proper, students had to rate 15 validated items on a 7-point Likert scale. The overall results (Figure 7) show how students felt intrigued by the activity ("I was curious about how the activity would progress", M = 5.9 points), and absorbed in the task ("The activity became the unique and only thought occupying my mind", M = 5.3).

Moreover, students affirmed they liked the activity a lot, especially the type of the experience ("I liked the type of the activity", M = 5.4) and its newness ("I liked the activity because it was novel", M = 5.6).

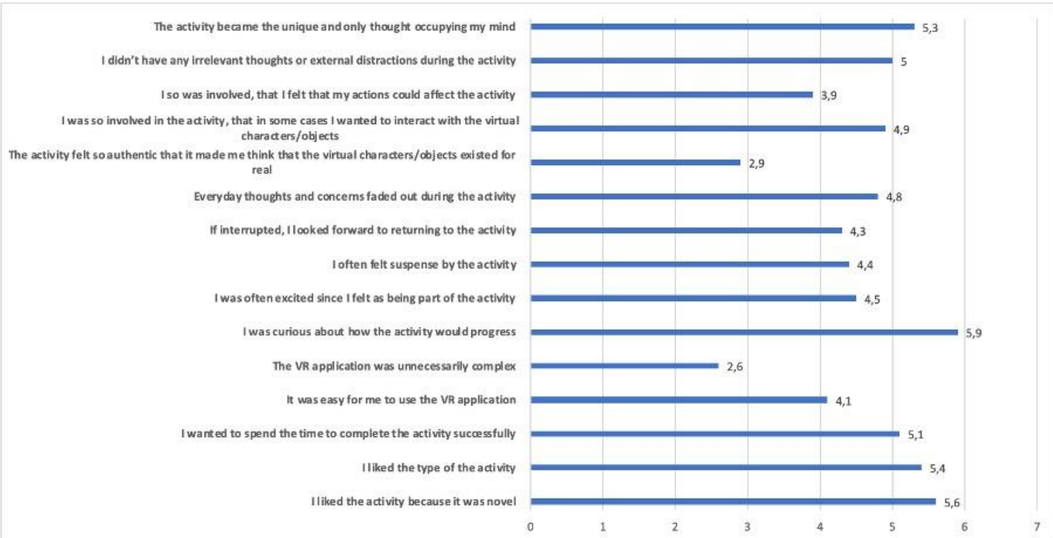

FIGURE 7 – RESULTS FROM THE ENGAGEMENT QUESTIONNAIRE – TOTAL AVERAGE

From a comparison between the two groups, very interesting differences emerge (Figure 8). The participants of the P&P group affirmed that their everyday thoughts and concerns faded out during the activity (+1.1 average point compared to VR group), and that the latter became the unique and only thought occupying their mind (+0.9 average point). The VR group participants, instead, revealed that they were so involved, that they felt that their actions could affect the activity (+1.2 average point compared to P&P group), and that, if interrupted, they looked forward to returning to the activity (+0.7 average point). Moreover, participants of the VR group declared that, according to them, the VR application was unnecessarily complex (+1.2 average point).

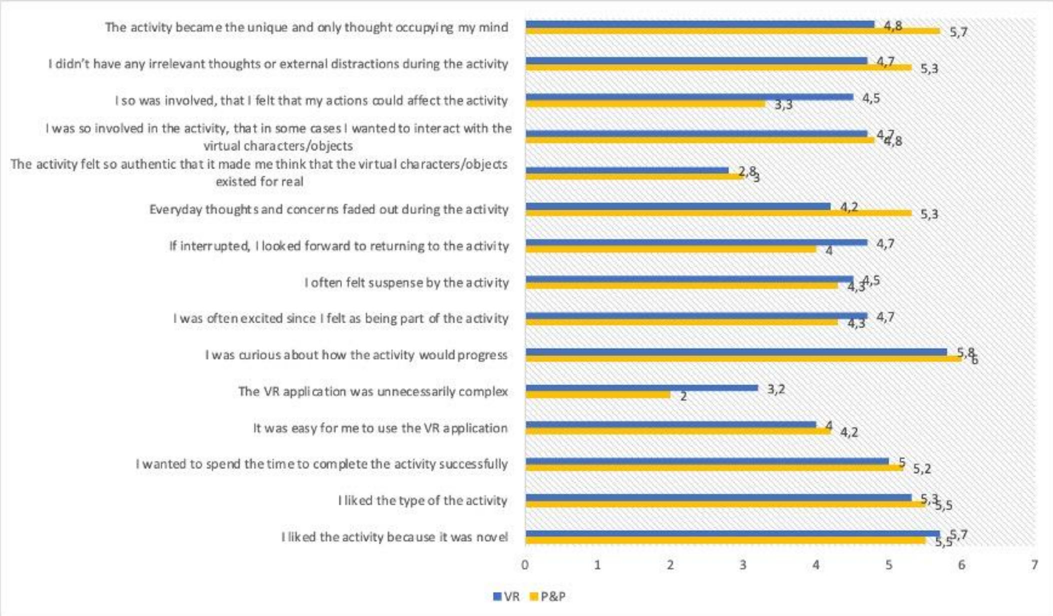

FIGURE 8 – RESULTS FROM THE ENGAGEMENT QUESTIONNAIRE – AVERAGE BETWEEN VR GROUP AND P&P GROUP

In the Presence Questionnaire, students had to assess 15 validated questions on a 7-point Likert scale.

The overall results (Figure 9) show that the visual and iconic features of the experience triggered the students a lot: the participants stated they liked the visual aspect of the immersive exhibition (the item "How much did the visual aspects of the environment involve you?" scored the highest average point, 6 out of 7).

Moreover, they appreciated the possibility to observe the artworks very closely and internally too (the questions "How well could you examine objects from multiple viewpoints?" and "How closely were you able to examine objects?" both obtained 5.4 average points).

Results highlighted once again how the students felt particularly involved in the immersive experience: the item "Were you involved in the experimental task to the extent that you lost track of time?" scored 5.4 out of 7 average points.

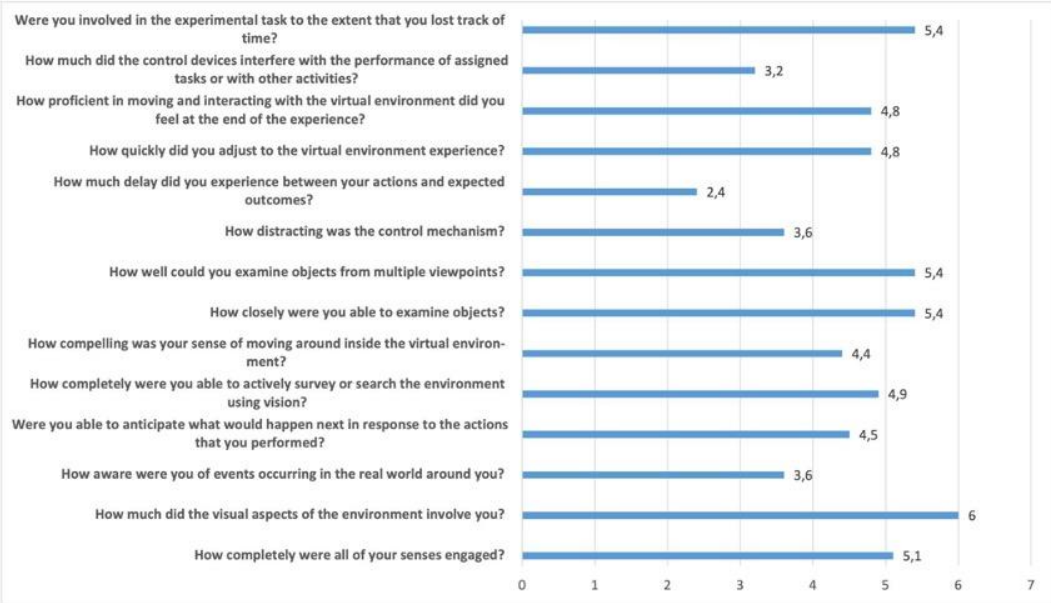

FIGURE 9 – RESULTS FROM THE PRESENCE QUESTIONNAIRE – TOTAL AVERAGE

Comparing the results from the two different groups (Figure 10), it is interesting to notice that the P&P group seemed to be more involved by the visual aspects of the virtual experience (+1 average point compared to VR group), and that the participants affirmed that they were able to actively survey or search the environment using vision (+1.2 average point).

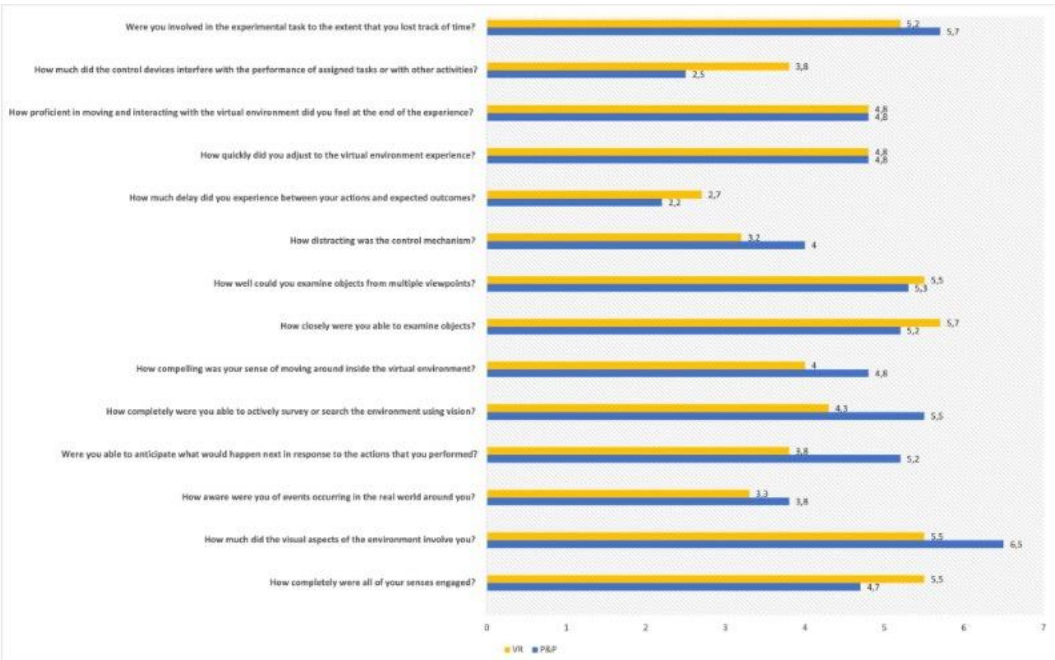

FIGURE 10 – RESULTS FROM THE PRESENCE QUESTIONNAIRE – AVERAGE BETWEEN VR GROUP AND P&P GROUP

On the contrary, the VR group showed a higher sense of engagement including all senses (+0.8 average point compared to P&P group).

The participants of the VR group stated to be less aware of events occurring in the real world than the other group participants (-0.5 average point). Moreover, even though they perceived the control mechanism as less distracting (-0.8 average point), they found that it interfered more with their tasks in the virtual environment (+1.3 average point).

4. Discussion

The descriptive analysis brought multifaceted results; for this reason, we propose a discussion about each of the three hypotheses mentioned above, trying to combine evidence collected from both the questionnaires and the interview sessions.

The first hypothesis (HP 1a) expressed our expectation that the preparation moment with VR would increase the students' mastery of the preliminary knowledge required to understand the artworks – compared to preparation with printed materials. This hypothesis was rejected.

Based on the results of the Preparatory Moment Questionnaire, we know that students in the VR group deemed the preparatory moment useful in order to collect information on the immersive experience on the comet. Combining this evidence with other quantitative data, we can assume that this information has been effective in generating learning related to the visual aspects of the experience. Students declared they improved, in particular, the ability to orient themselves in the immersive space. The P&P group, instead, benefitted more in terms of memorizing and understanding theoretical passages, which improved theoretical knowledge above all. It must be considered that the experimental setting may have had an impact on the participants (a participant in the VR group stated, "I feel like I didn't really have the time to assimilate what was written on the labels outside the atelier"). Still, we believe it is possible to conclude the following: students perceived traditional media (like pen and paper) as more effective to assimilate knowledge and memorizing information; by the contrary, they perceived VR as a more effective tool to deepen visual aspects of a learning object (Höffler et al., 2013).

This primary result is very close to the evidence supported by Makransky and colleagues (2021): in their experiments, students liked learning in IVR (Immersive Virtual Reality) more than from other traditional media, and felt a greater sense of presence, but they did not learn better, regarding the conceptual point of view.

Our second hypothesis was that preparation with VR would increase the sense of control on the technology – an important dimension of the broader sense of presence. In our reading, this hypothesis has not been ultimately confirmed by the data either. Indeed, it is true that – as emerged in the Presence Questionnaire – participants in the VR group reported that the control mechanism was less distracting compared to participants in the P&P group (-0.8 average point). At the same time, however, they declared that it interfered more with what they had to do in the experience (+1.3 average point). We interpret this seemingly contradictory outcome as follows. On the one hand, participants in VR gained familiarity with the control mechanism in the preparatory phase, so that the controls in themselves did not in principle require dedicated attention. On the other hand, the movements and the actions required subsequently to experience the artwork, which involved floating in space, were different from those practiced in the preparatory phase, which implied visiting a virtual exhibition venue as one would do in real life. Therefore, though at that point familiar in itself, the control mechanism came to interfere with the exploration of the work of art because its mode of employment was unfamiliar. Think about someone with a broken leg using two closed umbrellas as crutches: the umbrellas would not distract the user in themselves (the user knows what those objects are and how to handle them), but they would likely interfere with the aim of walking around, since it would be necessary first to figure out how to employ them in a way that is not the usual one. One of the interviewees provided an example of a type of movement that they had not been trained to in the preparatory phase and that had to be figured out directly in the artwork experience: "[…] sometimes I had a little problem when I had to take some… when I had to go upwards but in a really steep way, right? [...] So, I tried to move around, tried to do something different so and... well, I realized that probably you go forward to the place you're looking with your vision, right? So, I tried to look more and more upwards and it worked".

Based on the discussion of hypotheses 1a and 1b, it came as no surprise that hypothesis 2 was only partially supported. Results from the Engagement Questionnaire indicated that participants in the VR group were willing to go back to the virtual experience if interrupted (+0.7 average point). However, compared to participants in the P&P group, they also had a stronger perception that the VR experience was unnecessary complex (+1.2 average point). We explain this observation in light of the above-mentioned discrepancy between what users were asked to do during the preparatory phase and in the artwork experience, respectively. In this sense, the VR training may have backfired: as the data suggest, not having any exposure to VR at all (as it was for the P&P group) may have been preferable to having an incongruent one, which made the exploration of the artwork feel in fact harder. The impact of the perceived complexity of the experience on engagement can be estimated based on the Dynamic Occupation in Time (DOiT) model (Larson, 2004; Larson & von Eye, 2006; 2010). According to the model, the complexity and novelty of a given activity contribute to increasing the level of engagement in it. However, excessive complexity and novelty make the activity overwhelming, thus decreasing the engagement in it. Participants in the VR group may have experienced this second condition. On the contrary, participants in the P&P may have enjoyed appropriate levels of complexity, and thus enjoyed more the artwork experience.[3] This hypothesis is confirmed by the fact that these participants declared that their everyday thoughts faded out during this experience

[3] The two groups did not report different degrees of perceived novelty. See Figure 8.

(+1.1 average point compared to VR group), which became the only thing they were thinking about (+0.9 average point). These reports suggest the achievement of something similar to a state of flow (Csikszentmihalyi, 1975; 1988; 2014), a form of deep and pleasant absorption in given activities which in the DOiT model both results from and reinforces engagement.

Conclusions

In sum, in our study, VR preparation to a VR artwork did not offer the expected advantages. The immersive preparation mostly improved the perceived satisfaction and not the students' mastery of the preliminary knowledge required to understand the chosen work of art, as expected. Most strikingly, it did not result in improved control of the technology, which in turn plausibly determined a lesser degree of overall engagement.

Far from being discouraging, however, this outcome provides crucial directions for future research. As discussed, indeed, in our view this is to be attributed less to the VR technology in itself than to the specific content of the VR preparatory materials that we used. It is very likely that the latter were not as effective as expected, because they detached in important respects from the experience they were leading to.

The conclusion we can draw is that, in view of successful teaching, a careful design of the VR content deserves at least as much attention as the choice of VR technology itself over alternative options. Therefore, while conceivable as a limitation of our study, having tested our hypotheses on the described VR artwork and its associated preparatory materials, at the same time, provides essential directions for future research in the field of technology-assisted education.

A more obvious limitation of our work was the reduced number of participants. This is justified by the pilot nature of our study. However, the same study should be replicated with an increased sample in order for its provisional results to be consolidated. Future research may both use the same VR materials and test new ones. By doing this, it would be possible both to confirm our provisional conclusions and to test our new hypotheses concerning the importance of a congruent preparation to the VR experience.

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