Innovative tools for teaching geosciences: the case of immersive videos

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ABSTRACT

Innovative digital tools such as immersive videos or augmented reality can prove to be useful for university teaching of geosciences, which allow for the exploration of space, the vision of places, landforms and landscapes and the understanding of the ongoing processes even without having to carry out educational field excursions. These technologies -initially introduced and tested during the COVID Sars pandemic restrictions- can now be used to allow a large number of students to observe the territory and its features without the physical, economic and temporal limitations that instead characterize normal field teaching. In this contribution, we present the immersive teaching experience carried out at the University of Milan starting from 2019 and the students' appreciation of it.

KEYWORDS: innovative digital tools, immersive videos, geo-education, glacial landscape.

INTRODUCTION

Several scientists (e.g., Scanlon, 2014; Georgopoulou, 2021; Frigerio et al., 2021), with the aim of increasing consciousness and awareness of people about climate change and its effects, are testing new strategies for sharing knowledge and make research outcomes more understandable to the general public. In particular, Geo-education requires even more new tools to involve and facilitate students in improving their knowledge and competences in Earth Science; among the others, 3D models (Bollati et al., this volume), augmented reality and immersive vision are the most innovative approaches (Diolaiuti et al., 2021). Many studies evidenced the pedagogical value of immersive experiences as well as their role in transferring knowledge to students who experience them (Guillaume et al., 2016). These authors also outlined the role of games based on such new technologies in term of "immersion and persistence", able to trigger more motivated behaviors. According with Dubey et al. (2023), immersive experiences, together with 2D and 3D spatial experiences, represent the evolution of metaverse. Pear review papers resulting from the use of the keywords "immersive vision" and "education" in the online database (Scopus survey 16/04/2023) show only one work in 1994 (Lampdon et al., 1994), very few papers until 2010 -except for 2007 and a progressive increase of works in the latest period, thus giving a total number of 142 papers. This increase is highlighting a growing interest on immersive vision to support education.

This paper contributes to this topic reporting the main results obtained in an experiment planned, developed, and performed by the University of Milan to prepare an "immersive experience" (i.e., an inclusive educational tool). This immersive experience permits visiting the Forni Glacier (Stelvio National Park, Italy, fig. 1) to the largest possible number of students. Forni glacier is still today one of the widest glaciers on the southern side of the European Alps and it is considered one of the most important "open air" laboratory for both researchers and students. Indeed, researches performed in this area cover a wide range of issues including glacial history (Diolaiuti and Smiraglia, 2010; Pelfini et al., 2014), glacier micrometeorology and mass balance (Senese et al., 2014), ongoing

surface and volume changes (Fugazza et al., 2019) as well as Geo-educational experiences (Bollati et al., 2015; Pelfini et al.,2016; Diolaiuti et al., 2021).

During the proposed digital experience students can not only visit an alpine glacier but they also are virtually part of the scientific team who is studying and surveying the glacier.

Fig. 1 - The Forni Glacier in the Stelvio National Park (from Branca Hut, August 2009).

The choice to prepare a virtual experience as an educational and disseminative tool instead of a simple documentary was based on the most recent findings in the field of psychology (e.g., Killingsworth & Gilbert, 2010) and on the key concepts of pedagogy and disciplinary education concerning laboratory activities and field work (e.g., Orion, 1993, 2003; Pelfini et al., 2010, 2016, 2019).

We decided to propose not only lessons but also experiences in order to be more effective in sharing contents and in making them understandable to students. In fact, in a classroom, students are spectators, while if they enjoy an experience, they become protagonists and the result is deeply different in terms of both satisfaction and memorization. Field and lab educational activities allow students to understand the natural landscape and its driving processes, placing them in the correct spatial and temporal perspective. In particular, by experiencing the glacier environment and visiting a retreating glacier, one can understand the impacts of climate change on the cryosphere (see Diolaiuti et al., 2021; Garavaglia et al., 2010, 2012). Field and lab activities are common in university courses concerning natural and environmental sciences, nevertheless, in some cases, it is not possible to enjoy a real open-air experience; this is the case, for example, of people with disabilities and health problems. They cannot enjoy a safe trip on an alpine glacier, or they could do it but with severe limitations and constraints. More recently, the global COVID-19 pandemic has further exacerbated such limitations and require solutions to bring outdoor sites, and in particular mountain glaciers, closer to students. In this paper, we present the virtual -immersive- experience we prepared to visit Forni Glacier (Fig. 1) and the related survey to evaluate its educational and disseminative efficacy. We consider this tool a suitable solution when fieldwork and fieldtrips are not possible or to accompany traditional educational methodologies.

An “immersive experience” is an experience, which pulls a person into a new or augmented reality, enhancing everyday life (by making it more engaging or satisfying) via technology. Often, one or more technologies are linked together for the purpose. Through an immersive experience a student changes from spectator to protagonist. Being protagonist means being present in the place described, observing what the experts do in the field (Perotti et al., 2020). This means “experiencing” and not just learning by observing. Experimenting, according to the well-known “hands on” didactic approach, allows memorizing and preserving in one’s own experience what is explained and illustrated, with very different effects on the quality and speed of learning.

The peculiarity of educational immersive videos is that not only the viewers are the protagonist, but also the teachers (i.e., the specialists who illustrate their own research or explains the site) are protagonist as well, and address the virtual visitors directly, speaking and explaining to them the various phases of the work carried out in the field. The protagonists are therefore students and teachers, and this is fundamental in the learning process. In a normal documentary or didactic video, the specialists explain to everyone, while during the immersive experience the specialists speak to the virtual visitors, establishing a relationship with them. From an educational point of view this is a real revolution.

MATERIALS AND METHODS

In the case of the immersive experience on an Alpine glacier, the researchers and technicians of the University of Milan based this experience on 360° contents. A 360° content is a video you can

“explore”. This is possible thanks to 3DoF (Degrees of Freedom) experiences: standing at a fixed point, the virtual tourers can look in any direction turning their head left or right, tilting it up or down, or pivoting left and right. A 360° content is obtained by means of an 8-sensor video camera (fig. 2) that shoots in all directions of space (360° horizontally and vertically, as it is also possible to view the ground and the sky of the investigated site).

Fig. 2 - The 8-sensor video camera in the foreground and an example of field work in the background. vio National Park (from Branca Hut, August 2009).

The acquisition by the 8 sensors is synchronous, and it is added to the acquisition of the ambient audio. In this way, the virtual visitors can hear the real noise of the glacier, the water flowing on its surface, the creaking of the ice under the crampons of the researchers, and the audio of the experts who are speaking to the virtual visitors explaining their research. The audio and video files are postprocessed and coupled in the laboratory and this process leads to a 360° immersive product that can be used with special VR (Virtual Reality) headsets (Fig. 3).

RESULTS AND DISCUSSIONS

During summer 2019 scientists and technicians of the University of Milan acquired several 360° videos on the surface of the Forni Glacier and in its glacier foreland. The videos describe the main research activities such as sampling ice and meltwater, measuring ice ablation, downloading data from the supraglacial automatic weather station, etc. The 360° videos of Forni Glacier have been captured following the most recent indications for teaching through audio-video means that recommend proposing experiences or films that are a few minutes long to maximize their effect in consideration of the average attention time. For this reason, all videos have a duration of less than 5 minutes to prevent boredom or distraction from limiting the effectiveness of the experience. Researchers always address the virtual visitors directly, involving them in the work carried out or in the explanation provided also through questions. The 360° videos were initially shot in Italian only, as the intended first use was for students of the University of Milan. Afterwards, the presence of international Bachelor and Master degree courses at the University of Milan and, consequently, of an international audience, suggested subtitling the videos in English, to make them usable to non-native Italian virtual viewers. The 360° videos presently available in English too are: i) Glaciers are witnesses. They are the best evidence of Climate Change; ii) Short, black and full of holes! How is the glacier tongue changing; iii) The plastic-made glacier. A unique case or a common situation? iv) Not only harmful: bacteria also have positive features! The most recent microbiological research on Alpine glaciers; v) White and red snow! How the UNIMI glacier AWS helps describe snow accumulation on glaciers.

The 360° videos were designed to be used firstly through VR headsets such as Oculus Go; these are commercial viewers commonly used to enjoy video games or immersive play experiences. After putting on the VR headset, the virtual visitors just need to turn around moving the head to explore the virtual space without the limits commonly imposed by the screens or the space shot. A further advantage of these devices is that the virtual visitors are really immersed in the experience and are therefore isolated for a short time from external reality and therefore from distractions that commonly occur in the case of traditional documentaries. Nevertheless, in order to increase the fruition of this innovative experience, the researchers from the University of Milan, modified the multimedia product, to make it usable also via smartphone or tablet. The web site that contains the immersive experiences subtitled in English can be reached without the need of specific apps at the link https://video.unimi.it/video/forni_glacier_360/ or using a QR code (see fig. 4). Once on the website, the visitors can choose which experience to enjoy using their device to navigate the entire space of the visit. Navigation is still at 360°, the only limit is the lack of isolation from the outside world that was guaranteed by the VR headsets. This can be overcome by using padded headphones. The advantage of this technology is that the virtual tour can be experienced everywhere (e.g., at

Fig. 3: The special VR (Virtual Reality) headsets used to experience the virtual visit to the Forni Glacier.

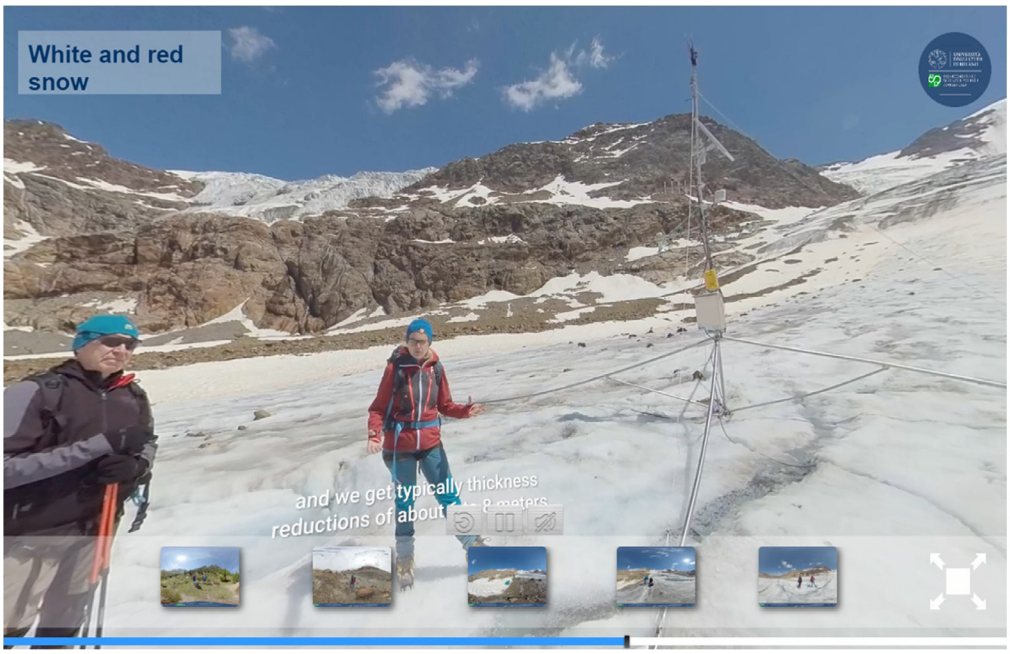

Fig. 4 - An example of the virtual experience on the Forni Glacier available at the link https://video.unimi.it/video/forni_glacier_360/ or using the QR code.

home or in a hospital) and not in a specifically suited room (e.g. classroom, museum).

In 2019 and in 2020- before the COVID 19 pandemic- the immersive videos developed by UNIMI were shared to about 1000 people via VR headsets and the results obtained were partially presented and discussed in a paper by Diolaiuti et al. (2021). After the pandemic crisis, in the a.y. 2022-2023, the version of the immersive videos subtitled in English and usable via QR code were shared to about 400 students of the University of Milan attending the Bachelor degree course in Natural Sciences (bachelor degree class L32) and the Bachelor degree course in Geography (bachelor degree class L6). The sharing of the videos took place after the students had attended traditional physical geography lessons and had therefore already received conventional explanations, information and descriptions relating to cryosphere, glaciers and the impacts of climate change on them.

Together with the QR code to use the immersive videos from their own devices (smartphones, tablets, laptops), the students also received a link (https://forms.office.com/e/ApqJ99chre in Italian, the English version is available at the link https://forms.office.com/e/XN8cKGiPGq) to access a form developed with the Microsoft forms application (educational license Microsoft© and Office 365© provided to all teachers and students of the University of Milan). The form was developed to evaluate the students' appreciation of this innovative teaching proposal and its effectiveness in making people understand the active processes and the effects on the glacierized high mountain landscape.

The proposed form is in Italian as the 400 students who took part in the test were all native Italian or foreign speakers with a written and spoken Italian level of B2 or higher.

The Form is anonymous and the data are analyzed only in an aggregate form.

This first test on the educational effectiveness of immersive videos was aimed at university students only in this phase as, after the restrictions imposed by Covid, such an activity in secondary schools was not yet possible. In the coming months, the proposal of immersive videos and the verification of their effectiveness is planned also in some high schools in cooperation with teachers of geography and natural sciences.

The students who answered the questionnaire are 20% of those who have experimented the immersive videos and both males and females were equal in number (Tab. 1).

About 40% of those who answered the questions were enrolled in the Bachelor degree in Natural Sciences while 60% were enrolled in the Bachelor degree in Geography. Initially, the students invited to experience the immersive videos and answer the questions were equal in number for the two bachelor degree classes, but Geography students resulted more sensitive to participating in the experiment.

For 41% of the students this virtual experience was the first one, while for 53% this was not the first virtual experience but the previous ones all took place outside the university. This indicates that these methodologies for teaching purposes still have a very limited application and, in fact, only 6% of the students had experimented with virtual tools in university teaching.

To the question "Have you ever seen a glacier?" only 28% answered positively by choosing the option indicating that they had also made an excursion, while 31% answered that they had actually seen a glacier but only from afar and 13% answered that they had seen it from close but without exploring it directly. 3% answered that they had never actually seen a glacier and 25% answered that they had only seen a glacier in TV documentaries or on the web. It is clear that 28% of the students have never had experience of field teaching in relation to glacierized mountains

Table 1: Questions and answers given by people who tested the virtual immersive videos (results are reported as % values on the total).

Question	**Answer 1** (%)	**Answer 2** (%)	**Answer 3** (%)	**Answer 4** (%)	**Answer 5** (%)
Gender	Male (49%)	Female (49%)	No answer (1%)		
Which three-year (Bachelor) degree class are you enrolled in?	Geography–L6 (60%)	Natural Science-L32 (40%)			
Did you take a physical geography or introductory earth science course in your major?	Yes (100%)	No (0%)			
Before this virtual cultural experience (not considering video games) had you done any others?	No, this was the first one (43%)	Yes, I had done others (augmented reality, 360 vision, etc..) in extra-university settings, i.e. holidays, museums, games, etc.. (53%)	Yes, I had done others (augmented reality, 360° vision, etc..) in a university setting (4%)		
Have you ever seen a glacier?	No (3%)	Yes, in TV documentaries or on the web (25%)	Yes, from afar (31%)	Yes, I made an excursion on it (28%)	Yes, I had seen it from close but without exploring it directly (13%)
Have you watched all the immersive films proposed?	Yes (63%)	I opened them all, but stopped them before the end (16%)	Just a few, that I chose based on the title I found most interesting (22%)	Just a few, chosen at random (0%)	
the videos are describing...	Only the characteristics of glaciers (0%)	The link between climate and the history of the glacier (0%)	The characteristics of the Mountain system (0%)	Highly current issues, such as the impacts of climate change and the effects of pollution on fragile high-altitude areas (100%)	
Did you know anything about glaciers and their variations before seeing these videos?	Yes, thanks to TV documentaries and material found while browsing the internet (16%)	Yes, thanks to lessons and seminars held at the University (84%)	No, I had never addressed this topic in a university setting (0%)		
Are you interested in the topic of climate change and its impacts?	Yes, and I also participated in Fridays for Future (14%)	Yes, and we addressed it in class (84%)	Yes, but unfortunately we did not address it in class (0%)	No, I'm not interested (0%)	
Before viewing the immersive videos, did you know what the surface of a glacier was like? Have you ever seen a crevasse or a hole?	Yes, because I visited a glacier (26%)	Yes, thanks to photos, videos and educational materials (43%)	Yes, thanks to photos and videos found while browsing the internet (20%)	No (11%)	
Before seeing the immersive videos, had you ever heard of microplastics and their spread even in the mountains?	Yes, I knew the problem and I knew that microplastic reaches high altitudes (78%)	Yes, I knew the problem but I thought it was limited to seas and rivers (22%)	No, I was not aware of this environmental problem (0%)		
Is voice-over useful in the immersive films?	Yes (88%)	No (0%)	I do not know (12%)		
Were you pleased to be able to hear the sounds of nature (wind, ice crunching under the researchers' crampons, flowing water) in the video?	Yes (100%)	No (0%)	I think it's irrelevant (0%)		
While you were watching the videos, did you often navigate 360° exploring the space around you, without the limits imposed by a normal video or documentary? Did you like it?	Yes, I browsed the video exploring the space and it helped me to enter more into the proposed experience and to better understand the explanations given by the researchers (91%)	Yes, I explored the virtual space but this distracted me from the explanation and I had to hear it again several times (3%)	No, I did not explore the virtual space and I remained focused on the explanation (6%)		

Question	Answer 1 (%)	Answer 2 (%)	Answer 3 (%)	Answer 4 (%)	Answer 5 (%)
Do you think this type of film could be useful for studying topics on nature and landscape?	Yes (100%)	No (0%)	I do not know (0%)		
When do you think it is most useful to watch immersive videos	Before the University lectures dealing on those topics (37%)	Following the University lectures dealing on that topic (63%)	As a substitution of the normal lectures given by teachers in the university classrooms (0%)	I consider them not useful (0%)	
Please choose the glacier feature that you consider most impressive in the videos	The effects of climate change: where there are now larches, juniper, rhododendron and pasture, in the past there was a glacier (32%)	The features characterizing glacier surface: ice, debris coverage and melting waters which work together (20%)	Glaciers are not pristine environments : microplastics is present into glacier ice and in supraglacial rock debris (30%)	Glaciers are full of life: bacteria and micro organisms live into glacier ice and in supraglacial rock debris and melting waters (9%)	Red snow and supragclacial automatic weather stations (9%)

and have knowledge and skills resulting only from classroom teaching and from studying books and manuals.

63% of the students who replied to the questionnaire have viewed all the immersive videos, 16% admitted to having started them all but having viewed them entirely only in small numbers, and 22% of the students admitted to having seen only a few, choosing them on the basis of title. It is evident, from this answer, that despite having produced immersive films of a duration lower than the average attention span for multimedia products (generally 5 minutes according to directors and sector specialists), the ability to complete the vision of a product is however limited to about 2/3rd of the public. Moreover 1/5th of the students choose the content to view only on the basis of the title, which must therefore be captivating and capable of arousing curiosity.

All interviewees acknowledged that immersive videos deal with very topical issues such as climate change and its impacts.

Most of the students (84%) stated that they knew something about these topics thanks to the lectures and seminars attended at the university, while 16% answered that their knowledge on these topics derives mainly from extra-university activities and web browsing. These users did not remember or did not follow the lessons that had been offered on these topics in both the Bachelor degree courses involved in the experiment. Considering that these students nevertheless lent themselves to the experiment, watched the videos and answered the form, perhaps this indicates that traditional teaching has not managed to capture their attention and their interest in the diversity of the virtual experiment. 88 % of students answered that they were interested in the topic of climate change and 12% declared that they had also taken part in the “Friday for Future” events to raise awareness among citizens and politicians on the topic and its consequences.

To the question “Before watching the immersive videos, did you know what the surface of a glacier looked like? Have you ever seen a crevasse or a hole?” the answers obtained confirmed the previous ones relating to having actually seen a glacier. In fact, 28% who have seen and visited a glacier answered that they had seen these epiglacial landforms while the others reported having seen them thanks to university lectures (38%) or thanks to websites and material found online (22%). 13% of students have never seen these forms of epiglacial landscape before immersive video, not even through traditional video or documentary.

Since one of the immersive videos is related to the presence of microplastics on glaciers, students were asked in the form if they were aware of this problem. All answered that they knew the problem of the spread of microplastics even on glaciers and 22% replied that they did not believe that this was such a significant problem for glaciers and that they only took note of it by watching the immersive videos.

88% of the interviewees appreciated the voice-over explaining the site and the research carried out and 100% of the students appreciated the real ambient sounds and noises such as the crunching of the ice, the flowing of the water or the blowing of the wind. This indicates that the more senses are involved with realistic experiences, the more engaging they are for students and will lead to remembering the experience and the content conveyed.

While watching the videos, 91% of the students experienced free 360° navigation to explore the space, and 100% of the students believe that this tool is useful for studying, understanding and learning the landscape (forms and processes). 63% of students believe that these multimedia products are more useful after the normal frontal lessons held by the teachers, while 37% would prefer to view materials of this type before the teachers’ lessons.

As far as the overall satisfaction is concerned, it was very high and in the free answers everyone reported the usefulness of tools like these to complement (not to replace) traditional teaching. Among the few disadvantages reported by about the 3% the possibility of getting distracted with the 360° navigation which for some is so captivating that they no longer follow the explanations.

CONCLUSION

The experiment conducted, albeit on a currently limited sample of students at the University of Milan who follow courses in the field of geosciences, is positive. All the students interviewed were satisfied with the proposed virtual experience and agree on

its effectiveness in completing traditional classroom teaching or single study on books. Although the majority of students indicate that they appreciate these proposals after the traditional lessons, upon completion of them, a small number instead replied that they would prefer to view these materials before the lessons, perhaps to generate more interest and curiosity and therefore maximize the results.

To better evaluate when it is best to offer these tools, we have planned a new experiment that we will carry out in the academic year 23-24 during which we will divide the sample of students into two equal parts in terms of number. We will offer to the first sub sample the videos and the form after the traditional frontal lessons (as in this case) while the second sub sample will be able to watch the immersive videos and the test before the classroom lessons. Only with this dual modality, we will be able to effectively evaluate which strategy is more effective and give more precise guidelines for the application of these tools in the teaching of geosciences.

The verification of the educational effectiveness of immersive videos conducted on university students only, due to the restrictions imposed by COVID, was the first necessary step in preparing a work protocol that could also be replicated in high schools. The strengths and weaknesses of the method that emerged in these first test phases will make it possible to develop suitable protocols both for the best use of immersive materials (before or after traditional teaching) and for evaluating the didactic and pedagogical efficacy of these tools and the popularity among younger students.

The answers collected also indicate that students find it difficult to complete the whole experience (although it requires less than 5 minutes per video) and a good number of the interviewees admitted to viewing only some videos and with a choice based only on the title. These data must make us reflect on how to arrange these materials so that they are truly chosen and used by the students. Another point to be considered is the small number of students who have actually experienced an excursion in the mountains and the vision of glaciers even from afar. In this sense, the virtual experience could be a useful tool for arousing curiosity and suggesting to these students real excursions in the future.

In conclusion, therefore, these virtual tools can really complete the teaching of geosciences. Nevertheless they also require careful preparation to make the products usable and used by students. Further tests and experiments are therefore needed to improve preparation and use protocols and guidelines.

The results obtained make it possible to design the most suitable video titles and to formulate the most suitable and targeted questions for a different school audience in the verification tests. The authors will prepare a workflow for high school teachers useful for self-management of immersive vision (with movies on smartphones or laptops). The next step will be to collaborate with secondary schools (already linked to the University of Milan for dual training – PCTO- projects) so that teachers can proceed by inserting these activities in their program, becoming not only direct protagonists for carrying out the activities but also for the evaluation and verification of both contents and student satisfaction.

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