Chapter 12
Evaluating Augmented and Virtual Reality in Education Through a User-Centered Comparative Study: SmartMarca Project

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ABSTRACT

Augmented and virtual reality proved to be valuable solutions to convey contents in a more appealing and interactive way. Given the improvement of mobile and smart devices in terms of both usability and computational power, contents can be easily conveyed with a realism level never reached in the past. Despite the tremendous number of researches related with the presentation of new fascinating applications of ancient goods and artifacts augmentation, few papers are focusing on the real effect these tools have on learning. Within the framework of SmartMarca project, this chapter focuses on assessing the potential of AR/VR applications specifically designed for cultural heritage. Tests have been conducted on classrooms of teenagers to whom different learning approaches served as an evaluation method about the effectiveness of using these technologies for the education process. The chapter argues on the necessity of developing new tools to enable users to become producers of contents of AR/VR experiences.

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INTRODUCTION

In classical education systems imperfections and challenges induce teachers to use new methods to improve the level of learning (Teferra & Altbachl, 2004; Luna Scott, 2005; Frey & Osborne, 2017). For this purpose, technology is a helpful aid in education, which allows to ease the learning methods, increasing the performances by introducing suitable technological materials (Richey, Silber, & Ely, 2008). Mainly, in the Primary school thanks to the didactic paths that are closer to the learning transmitted through the game, the preferential model of Virtual Reality (VR) and Augmented Reality (AR) applications, a great development of this disciplines has taken place. Some disciplines are more suitable for using these novel didactic forms, as for example sciences (Chen, Liu, Cheng, & Huang, 2017). The scientific disciplines have a major field of application in this innovative learning methodology and moreover, since these mobile devices are easily used by the younger generations, is established a greater familiarity and confidence during the learning process (Pierdicca, Frontoni, Pollini, Trani, & Verdini, 2017), and they take on the form of play or enjoyable quiz. Novel terms are coined as "learning by searching" and "Inquiry based science education" (Yin, Han-Yu, Hwang, Hirokawa, Hui-Chun, Flanagan, & Tabata, 2013), that are able to translate the different implemented processes through the creation of a knowledge based on researches, surveys and modelling construction. Taking into account different disciplines, the possibility of being completely immersed in monuments, or deepening in real time the contents of paintings or sculptures, without losing contact with the surrounding environment, is essential to enjoy an immersive and interactive experience of the work itself (Di Serio, Ibáñez, & Kloos, 2013; Naspetti, Pierdicca, Mandolesi, Paolanti, Frontoni & Zanoli, 2016).

For the students the process of learning requires, beyond the immediate response to the content proposal, even their permanence in time. The competences must generate an ability to understand and re-elaborate the information acquired to produce transversal and multidisciplinary skills. So an essential aspect is to use the technologies without weakening the ability of the students to create their own heritage of skills, refining cognitive techniques through their study and personal reworking. During the didactic activity, modulated on the class and on the single students, the use of technologies could lead to a method of work that is not flexible and can be modelled on the variable context of the students. The learning experience is modified with technological means (Dede, 1996) so it is important to study the effects of these technologies on learning, in particular on the student's ability to reuse the learned lessons in different fields. A certain effect is that the students, through their technological skills, can build paths that are more familiar to them. A real learning requires a more careful path to the relapse over time of the educational activities carried out by AR/VR technologies.

The aim of this work is to evaluate the real performances of AR/VR technologies for didactic purposes, considering their effect on the cultural and personal training of the students through the use of digital tools that involve all the aspects related to teaching and learning. The evaluation must also consider the ability to re-elaborate the learned knowledge. The work carried out with this research intends to be a contribution to the studies on the AR and VR applications in the educational field, evaluating as the contents and methods of these new educational paths can improve the real learning and how through a long-term educational path it is possible to direct the student towards a cognitive process and re-elaborate the learned knowledge. The test was executed inside the SmartMarca project, briefly described in Section 3. The platform underlying the project was specially created to handle AR/VR contents for cultural heritage located in the south part of the Marche region, in Italy. Since the students are oriented towards this kind of technologies, several experiments were produced exploiting and testing these users, with

particular attention to the evaluation of AR/VR potential for learning in the field of Cultural Heritage (CH) and obtaining meaningful results in terms of the multimedia experience.

BACKGROUND

Studies revealed that AR and VR have a great potential to help students to improve their knowledge and skills. In fact the connection between AR/VR and education makes the teaching and learning experience more efficient and appealing (El Sayed, 2010; Crosier, 2002; Kaufmann, Schmalstieg, & Wagner, 2000). In this way, students not only better learn, but also the learning processes reach a more accurate knowledge (Christou, 2010; Sotiriou and Bogner, 2008). The work of Gargalakos, Giallouri, Lazoudis, Sotiriou and Bogner (2011) has demonstrated that the technology has much enhanced the learning results increasing the curiosity of the students and their willingness to communicate and share their enlightening experiences with other students, their anxiety to use new technologies and acquire knowledge having fun and living virtual and current realities. However, there are challenges and disadvantages in the use of AR/VR as educational tool in most classes of the world (Ardiny & Khanmirza, 2018). The first problem is that implementing AR/VR systems is expensive. The second problem is the lack of realism for VR or AR simulations. The third problem concerns health problems and physical effects on students. The head-mounted-displays (HMD) are relatively heavy and can cause fatigue to users after a long period. Lenses in an HMD may obstruct the view. Another side effect that is not limited to HMD is the disease of the simulator and seems especially in virtual reality experiences. The fourth challenge is related to the limitations of the hardware. Although recent hardware developments have improved AR and VR demonstrations, the limitations could reduce a high level of user experience.

AR Applications

AR can be defined as an interactive experience in the real world where computer-generated objects and elements of the real world are linked together (Ardiny & Khanmirza, 2018). Initially, AR was born for scientific and research purposes. Since the eighties, AR has been applied for the first time in the military field in head-up displays, devices installed on the control panel of combat aircraft, which has allowed the pilot to test some parameters and flight data without looking away from the dashboard of the aircraft. Then the usefulness of this system has led to its spread even on civil aircraft. These are the years in which, also in the scientific and medical fields, analysis and study techniques are developed which involve the use of AR. AR is a technology available on different devices: 1) PC: it uses stylized black and white markers (ARtags) which are created ad hoc to be captured by the webcam and recognized by the PC, which superimposes the multimedia contents. 2) Mobile devices: such as smartphones and tablets. In this case we also speak about Mobile augmented reality (MAR): the device must be equipped with GPS, compass and Internet connection. Through the framing of the surrounding world, the webcam is able to detect "points of interest" (POI) to which other 3D multimedia contents are superimposed. 3) Dedicated devices: viewers with transparent or semi-transparent lenses, gloves and others.

In their work, M. Akçayır and G. Akçayır (2017) propose an interesting review where the different aspects of the use of AR in education have been highlighted. Studies have shown that AR technology offers many advantages when used in education (Cheng and Tsai, 2013). For example, AR helps students to begin authentic explorations in the real world (Dede, 2009). By displaying virtual elements next to real

objects, AR makes easy how events that cannot be otherwise observed with the naked eye, are observed (Wu, Lee, Chang & Liang, 2013). Saidin, Halim, and Yahaya (2015), focusing on the positive impact that these technologies have had on the community, affirm that AR can be defined as the new, extraordinary, way where it is possible to make concrete the abstract. Students can interact with a multimedia support animated and subject to changes: the possibility to interact with contents, facilitates the study above all of those who must analyse microscopic components of reality. According to Mark Billinghurst (Billinghurst, 2002), AR has the advantage of promoting collaboration among students, thanks to the possibility of recreating a real and common environment in which everyone can work. It creates involvement because it leads authentic materials and objects within the reach of the sensory experience of all learners. However, although many AR studies have been published, the educational advantages and related utilities of AR only recently have been explored (Chen & Tsai, 2012). To date there is not a comprehensive explanation of the educational effects and implications of AR (Radu, 2012). It is very important for a teacher to be able to assess the appropriateness of the applications to use in the classroom, especially in the case of AR, since most of these have not been born specifically for educational use. The first and fundamental criterion to deal with is the usability. In fact, the application that shall be used has the aim to satisfy the learning needs of the students, thanks to the intuitive access and use of the tools and ensuring the ease of understanding both the processes and the contents.

During his research, Nielsen (1994) established five fundamental requirements on which the concept of usability is based: ease of learning, efficiency of use, ease of understanding, reversibility of errors and satisfaction in use. Therefore, we can affirm that even if AR is not born for tutorial purposes, it has a huge exploitable potential in this field. For example, the AR interfaces are used in the medical field as a training tool that allows the students to visualize the inside of the human body and the various organs in 3D. In the chemical field, the AR has made the study of the elements interactive and attractive thanks to the 3D representation of their physical properties and of the reactions deriving from their combination. The possibility of scanning the most famous paintings to obtain real-time information has important implications in the teaching of art.

One of the most used apps on AR is the Aurasma app[1]. The software is free for both IOS and Android and is developed by the Autonomy company. Through this application, it is enough to frame a photo, a newspaper, and an image with a smartphone or tablet that immediately appears on the screen an additional related content. The added content could simply be a video, a link to a web page or more complex like a 3D animation. From the e-learning point of view, MAR has proven to be a winning solution (Etxeberria, Asensio, Vicent & Cuenca, 2012). In Garau and Ilardi, such as, a specific application was designed that allows people to download the contents related to the area of cultural heritage (CH) they were discovering. Given the enormous disposal of CH-related artifacts produced in recent years, contents such as building paintings have been increased, especially in the archaeological site. A good example can be found in (Garau & Ilardi, 2014).

In 2006, Wagner, Schmalstieg and Billinghurst developed a collaborative video game based on the educational game called Virtuoso. The purpose of this game is to order a collection of works of art based on their date of creation along a timeline with three different conditions: a paper, a PC and a PDA. The results showed that although the players were tested with three different game conditions, no significant differences were found in the educational results. It is interesting to note that the players preferred the paper and PDA version because it allows them to collaborate more effectively than the PC version. Furthermore, they chose the PDA interface as the most pleasant of the three conditions (Wagner, Schmalstieg & Billinghurst, 2006).

In 2009, Dunleavy, Dede and Mitchell designed Alien Contact!, a MAR game that focuses on teaching mathematics, language arts and scientific literacy to middle and high school students. The concept of the game is based on the scenario where the aliens landed on earth and work in teams. Students can interview virtual characters, collect digital objects and solve science, math and language problems to answer the question and find why the aliens have landed on earth. The results obtained from the study have documented the high involvement of students in the different case studies (Dunleavy, Dede, & Mitchell, 2009).

In 2009, Ardito and others presented a MAR game called Explore! with the aim of supporting during a visit and explorations of middle school students to archaeological sites in Italy. This game was played by groups of 3-5 middle school students in which each group was given 2 mobile phones and the site map on a sheet. The concept of the game required the students to explore important places on the sites supported by some tips provided on the phone by the game application. From the results of the study, it was shown that the students had fun playing with Explore! but in terms of learning, there were no significant differences (Ardito, Buono, Costabile, Lanzilotti & Piccinno, 2009).

Martín and others proposed an educational application called EnredaMadrid to make it easier for students to learn history. The goal of EnredaMadrid is to teach the history of the city in the 17_{th} century through previous online training and a later physical technological gymkhana. For the realization of this application, mobile devices based on geolocation and AR technology were used. The evaluation session was carried out through a questionnaire, and the results showed that AR certainly contributes to making learning more fun and motivating and that AR is the most proper tool for learning the history of the city (Martín, Díaz, Cáceres, Gago & Gibert, 2012).

VR Applications

Virtual Reality, unlike AR, is more widespread and known in the field of videogames and therefore young people are more familiar with the use of different devices that allow a VR vision in the various fields of application, not directly linked to the purely playful aspect. This familiarity constitutes an element in favor of the introduction of VR technology in a school educational path. Through the dissemination of video games, it is easy to offer students the use of devices such as visors and cardboard.

HMD used in combination with earphones and gloves produce an interesting immersive effect, not only in video games but also in educational applications. The user can be placed in an environment that reproduces simulation situations that facilitate emotional and sensorial involvement. An interesting example of the application of VR in training is the simulation of the risks in the construction site works. Living the fall from above in a simulated way allows the experience of the fall to be perceived in a realistic way and leaves the feeling of emptiness in the unconscious memory. The transmission of knowledge therefore passes through an experiential dynamic that allows us to broaden the aspect of student involvement in teaching practice. As result there will be not only a more correct behavior in the front of a risk situation, but also a more conscious ability to outline a work procedure that better complies with the normative requirements, as enriched by a direct practice that constitutes a heritage, the result of a training process developed in the field. There are different working sectors in which the application of VR performs the function of simulating dangerous situations for a correct and complete professional training. Rahimian, Arciszewski & Goulding (2014) describe the use of VR for the professional training of architectural engineering construction specialists. The direct vision of what is transmitted and its

involvement amplify the learning process. In particular, according to Classen: "the sense of seeing is the most important sense and it is most closely linked to reason" (Classen, 1997).

Introducing therefore the technology of VR in specific didactic sectors facilitates the action of learning, thanks to the direct involvement of the student who becomes active subject in the transmission of knowledge. The educational areas that are most suited to being VR systems application scenarios are technical and scientific. In fact, these sectors have aspects that can be easily reproduced in simplified and operational situations. They allow the student to reproduce in a concrete and visible way the application of formulas or theories that, relegated to the textbook, would be dry and not very comparable. The risk may be that this activity is interpreted only as a game and therefore detached from the learning process, which although experiential, must lead students to increase their theoretical and conceptual knowledge. The application of VR in the field of visual arts and architecture and in any case in all cultural heritage is particularly interesting (Bekele, Pierdicca, Frontoni, Malinverni, & Gain, 2018). Reconstruction of monuments, archaeological sites or works of art through viewers that allow you to immerse yourself in the building are engaging experiences, especially for a young audience that uses digital devices with familiarity. Technologies can serve a function similar to X-rays to show what is hidden underground or to increase an environment with virtual reconstructions of lost heritage (Clini, Quattrini, Frontoni, Pierdicca, & Nespeca, 2017).

Virtual reconstructions of lost heritage can promote, not only the rediscovery of otherwise unknowable places, but also spread a culture of protection of what is present and tangible. In using a VR device to move to a place rich in history, a boy can be attracted to discovering aspects and details that he would not otherwise read only through a direct vision. Therefore, in the technological approach the added value of the digital methodological language brought to the didactic action is enclosed.

In (Martín, Díaz, Cáceres, Gago & Gibert, 2012) the authors indicate three key aspects linked to any VR system: immersion, interaction and visual realism. The action to surrounding the user with virtual technologies and devices creates the immersion. (Wu, Liu, Wang & Zhao, 2015), e.g. virtual glasses, gloves with movement sensors, HMDs, surround sound, and any element that creates sensorial stimuli, or sensors that allows the user to interact with a virtual environment as in a real environment. So that VR simulates the real presence of the user in a virtual environment, which is classified as sensory-motoric, cognitive, and emotional (Holopainen & Björk, 2004). Moreover VR also creates an immersive 3D spatial experience when the users feel of belonging to a virtual world, which is affected by his perceived feeling (Benford, Greenhalgh, Reynard, Brown, & Koleva, 1998). To seem real, this perception requires real-time interaction, in order that the user requires instant feedback of his movements, position, and sensations. This feedback allows the user to react and send commands to a computer by using trackers, gloves, keyboards, or any other input device simulating real-world user's reactions.

Traditionally, the invention VR is traced back to a device designed and patented by the American director Morton Heilig (Mihelj, Novak & Beguš, 2014) and named Sensorama. Heilig, already at the end of the 1950s, had designed a television that allowed for a 3D viewing experience. In fact it was a cabin equipped with stereoscopic screens, stereo speakers, as well as a movable seat.

But it was not until the 1990s that we started talking about VR again, when the videogame industry was finally able to have functional technological equipment for mass production, and therefore products capable of combining high-profile performance and low costs.

In the primary classes of the Unified School of San Francisco and of the Polk County Public Schools complex in Florida, through the Nearpod educational platform[2], virtual tours of Easter Island, in Ancient Egypt, along the coral reef and even on Mars are offered to children. While, in California, at the Marin

School of the Arts in Novato, many of the classrooms have been reorganized to be more in line with the spatial needs required by the VR systems in use. In these classes, a wall was occupied by ultra-flat monitors on which the children create and manipulate scenes at 360°; on the opposite side, now without desks and chairs, a protected area was created in which students can use an optical device: HTC Vive headset.

On this side of the Atlantic, the Mendel High School in Opava, in the Czech Republic was the first European high school to create integrated courses with the latest generation of VR technology. In the current school year, the Czech high school offers science and history teaching units through the optical device, Oculus Rift headset, and the Leap Motion controller, a technology that, connected to the hardware, allows, through simple hand movements, rather precise human-machine interactions.

The virtual application, Google Expeditions[3] allows taking part in hundreds of virtual visits to the most evocative locations around the world (like the Great Wall of China, Mars, and more) but also in the depths of the oceans or in the most extreme space. It is a product specifically designed for classroom work. The dedicated site, in fact, has instructions and advice on how to best organize a virtual lesson addressed directly to teachers. The test may be produced with a mobile phone and a Google Cardboard headset[4]. A VR tour requires 360° viewing so that the participant overall observes the scene they are viewing. The user can look to the right, and they can look up or down, or they can go towards an object.

In the InCell VR app[5], the user is miniaturized inside a human cell and has the task of reaching, before the virus does, the nucleus of the cell, so that it can thus defend itself from any attack. To be successful, the user will have to move between mitochondria, cytoplasm and centrioles, closely observing their forms and functions.

The app Vatican[6] is an application that provides tours and information about the Vatican in Rome. Students can enter each room with High Definition pictures. This application is only available for 360 views and not Google Cardboard.

Cave Automatic Virtual Environments (CAVE) (Christou, 2010) is a tool supporting immersive VR approach there are, where the user is in a room where all the walls and the floor, are projection screens. The user can wear 3D glasses, feels floating in the projected world where he can move around freely. CAVE environments are still rather expensive, they need to have a specific space dedicated to them and they cannot be moved easily. All these characteristics make it difficult a widely spread use in education and didactic. However, CAVE technology is particularly used in cultural heritage education (Ott & Pozzi, 2008).

DESCRIPTION OF SMARTMARCA APPLICATION

The cultural and tourist heritage of the territories is one of the constantly argued issues in the national and European panorama. Within this scenario, the innovative and digital systems supporting managers and users are still under-utilized and require a cultural leap with respect to the issues of digitization of cultural heritage and tourism in general. The SmartMarca project[7] is positioned within this scenario with the main objective of bringing the Fermano within the main national trends. The objectives of the project concern the numerous benefits and added value for all the actors involved in cultural tourism deriving from the digitisation of CH, from its publication on the net and from its re-use, that is:

- The possibility for cultural institutions to promote itself, enhance the known and less known, tangible and intangible heritage, increase the flow of visitors, tourists and users on the internet, and diversify the offer according to the recipients;
- The possibility for creative industries to exploit the potential of digital cultural heritage to create innovative services for tourism using professional figures with specialized skills and competences.
- The possibility for territories and territorial aggregators: to improve the quality of information on digital cultural heritage held by cultural institutions, respond to the needs of the tourism sector, build and strengthen contacts and links with the chain of actors involved and have more elements to promote digital cultural heritage as a driving force for strategies in the tourism market.
- The possibility for small and medium enterprises in the tourism sector (hotels, restaurants, tour operators, service cooperatives) to have cultural content available and offer more effectively on the market.
- The possibility for the tourist to benefit from additional tools of knowledge in order to be able to virtually visit less known or more peripheral places of cultural interest, live or plan and personalize their own travel experience through the opportunities offered by the technology, particularly mobile.

The project intends to propose the implementation of targeted strategies for each main territorial characteristic through the use of innovative technologies that can be inserted in paths for the enhancement and dissemination of the landscape/cultural heritage in order to expand the proposed offers, promote them on a scale worldwide and to finally generate an added economic value. Since the territory of Fermano is very heterogeneous, five main characteristics have been identified:

1. architecture, civil and religious monuments;
2. archaeological sites;
3. little villages and enogastronomy;
4. hills, mountains and hiking trails following the concept of sustainable mobility;
5. picture galleries and pictorial cultural heritage.

Through the use of 360° panoramic photos it is possible to recreate an exciting experience in the territories of the Fermano, going to emphasize the small villages and for example, through the virtual reality and Google Cardboard it is possible to live the Fermano, going to interact with points of interests to obtain contents of various types (texts, images, audio and video) and exciting the end user.

The Fermano territory is rich in itinerant routes and it is important that all citizens have exhaustive information that better allows them to discover and exploit. To achieve this scope, it is necessary that through the use of technologies such as Beacons, it is the territory itself that communicates to the user the relevant aspects of the surrounding environment. The result is that the key points of the territory are transformed into sensitive areas.

Furthermore by applying AR to the main Fermano paintings, an innovative method is obtained that provides information and interactive contents, favoring the accessibility and learning.

Then, SmartMarca aims to improve the quality of the territorial cultural offer by using the advanced technologies such as AR and VR, beacons and geolocalization systems this in order to provide users contextual services when traveling in the territory. The main innovative aspect is the management platform, which is able to manage several contents and output through a single cloud based service. The structure

consisted of micro-services allows the managers of the platform to use different contents with different output. The common denominator of the project is the Senseable Space concept that defines a novel scenario where the user can use contextual services, but is simultaneously able to measure, analyze and reply accordingly actions, establishing a seamless information exchange (Osaba, Pierdicca, Malinverni, Khromova, Álvarez, & Bahillo, 2018).

For the question of this chapter, AR and VR application have been used to test multimedia for learning purposes and for these goals, contents can be used by the users through a mobile application, designed both for iOS and Android.

For the case of this paper, AR services are specifically designed to augment two of the most important paintings of the "Fermano", to increase accessibility and learn the painting itself. By using AR it is possible to identify a painting by framing it with the camera of a mobile phone to access augmented contents: emphasizing selected areas of the painting to give precise information on a specific feature, reproducing a video superimposed to the painting and visualizing appropriate images and texts in overlay. Concerning VR application, the image of Falerone amphitheatre 3D model is viewed. The users can interact with the image using VR headsets.

METHODOLOGY

The work described in this chapter was conducted following a rigorous methodology of study, divided into three main steps, described in the following: at a first stage, AR and VR have been studied separately, and then a comparison among the two technologies was carried out. The following sections follow this methodological approach.

AR Application: Rubens and Licini Paintings

An AR experience has been developed inside the SmartMarca project and it is related to the analysis of artworks belonging to the territory of Fermo: the "Adorazione dei pastori" by P.P. Rubens preserved in Palazzo dei Priori in Fermo and "Paesaggio" by Osvaldo Licini, present in the artist's house (museum in Monte Vidon Corrado). The app permits the augmentation of the artwork through tags that, deepening the critical contents of the paintings, propose a more attractive view both the details and the complete work. This project is mainly targeted for tourists, but with the aim to also use for didactic use that allows starting a first suggestion of knowledge of artworks in its fundamental contents. These tools have been employed to undertake an educational authentication path of AR. Some screenshots of the application running can be found in Figure 1. The research activity has been structured in different steps that can be summarized in the Table 1.

Didactic Methodology

In the secondary school curriculum, there is a first approach to the history of art through links that relates different disciplines and so students make a comparative reading of different including a synchronic and diachronic method of study. To the students, coming from the two-year period and the three-year period of a technical institute and a high school, were proposed the reading of the artworks using different methods, which provided a thorough introduction by the guide and/or the teacher. After the description,

Figure 1. AR application in front of the paintings
(a) "Adorazione dei pastori" by Rubens (b) "Paesaggio" by Licini

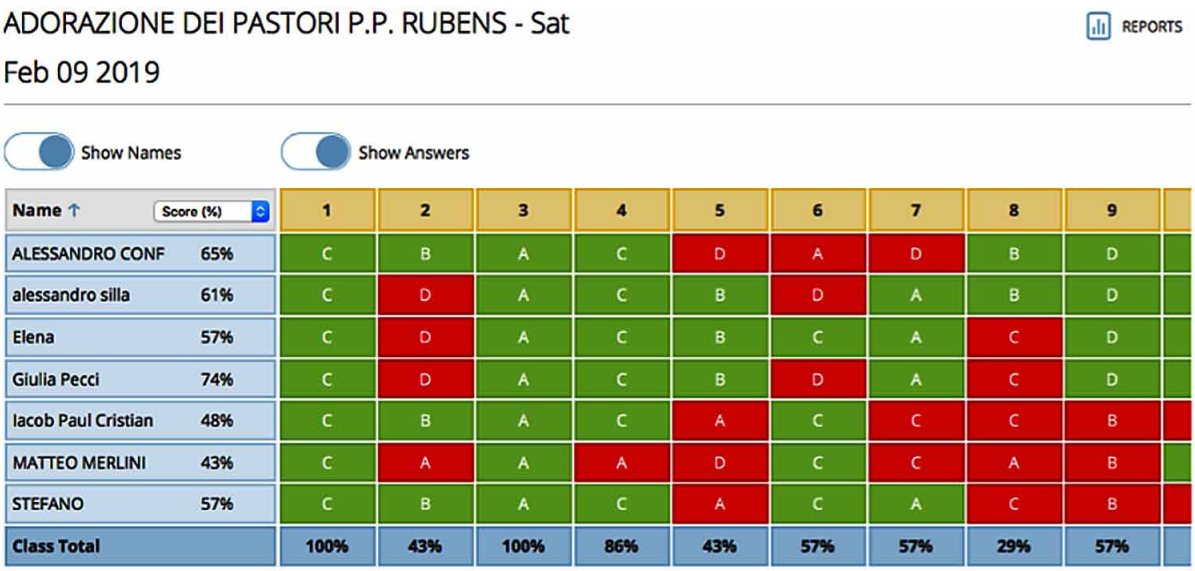
Table 1. First phase of the research path: description of the methodology used in the learning-teaching process, using AR application from SmartMarca project

First experimental phase				
With device	Explanation of the artwork by the teacher	Check online with the *Socrative* support	Data collection and statistical definition	Analysis, data comparison and conclusions
	Without explanation of the artwork			
Without device	Explanation of the artwork by the teacher			

the students using their smartphones had the access to the dedicated sector inside SmartMarca application. Through the painting they had access to AR content through overlay texts and the visualization of details, to which the markers were associated.

This information was subsequently verified through a series of multiple-choice questions included in Socrative application, an online application that allows verification and collection of results, data and statistics related to student learning. The questions included in the Socrative program and described also using images, were presented in table 3 and 4, found in the Appendix section of this manuscript. Questions have been organized with keywords that match with the overlap contents of the AR application, this in order to facilitate the link between the images and its related comments. Observing tables the questions had multiple choice (four options with only one correct) in order to have consistent data with a statistical meaning. Questions Q5, Q6, Q7, Q21 in table 3 are linked to the principal theme, chosen for its evocative value. Students have been asked to re-elaborate what was visualized in the app, to stress test their meta-cognitive learning. In the questionnaire related to table 4 questions to check the ability to re-elaborate contents and concepts are Q8, Q9, Q10, Q11, since they attempt to deepen some details of the painting like tree and house, the main theme of the whole painting. Figures 2 and 3 show the questionnaire results such as in the Socrative application used for this test.

Figure 2. Questionnaire data report "Adorazione dei pastori" of Socrative program



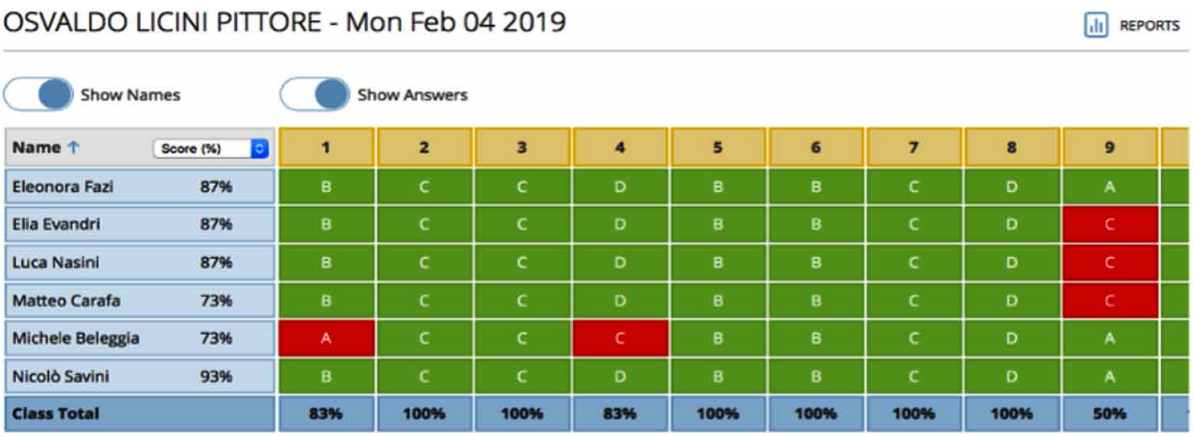
ADORAZIONE DEI PASTORI P.P. RUBENS - Sat Feb 09 2019

REPORTS

Show Names Show Answers

Name ↑	Score (%)	1	2	3	4	5	6	7	8	9
ALESSANDRO CONF	65%	C	B	A	C	D	A	D	B	D
alessandro silla	61%	C	D	A	C	B	D	A	B	D
Elena	57%	C	D	A	C	B	C	A	C	D
Giulia Pecci	74%	C	D	A	C	B	D	A	C	D
Iacob Paul Cristian	48%	C	B	A	C	A	C	C	C	B
MATTEO MERLINI	43%	C	A	A	A	D	C	C	A	B
STEFANO	57%	C	B	A	C	A	C	A	C	B
Class Total		**100%**	**43%**	**100%**	**86%**	**43%**	**57%**	**57%**	**29%**	**57%**

Figure 3. Questionnaire data report "Paesaggio" of Socrative program



OSVALDO LICINI PITTORE - Mon Feb 04 2019

REPORTS

Show Names Show Answers

Name ↑	Score (%)	1	2	3	4	5	6	7	8	9
Eleonora Fazi	87%	B	C	C	D	B	B	C	D	A
Elia Evandri	87%	B	C	C	D	B	B	C	D	C
Luca Nasini	87%	B	C	C	D	B	B	C	D	C
Matteo Carafa	73%	B	C	C	D	B	B	C	D	C
Michele Beleggia	73%	A	C	C	C	B	B	C	D	A
Nicolò Savini	93%	B	C	C	D	B	B	C	D	A
Class Total		**83%**	**100%**	**100%**	**83%**	**100%**	**100%**	**100%**	**100%**	**50%**

DATA ANALYSIS AND DISCUSSION

Figure 4 compares the results obtained making different testing method. The differences concern the rates of learning process by the students with or without the support of AR technology. Interesting is that Q8, Q9, Q10, Q11 questions have a higher percentage of positive answers combining lesson with AR (85.25%). Using only the app is not sufficient to reach a higher degree of in depth knowledge; hence the student is not able to elaborate meta-cognitive processes (less that 50%). The classical lecture confirms an average of 65% of right answers. These results demonstrate that adding AR increases the learning process, but its alone application is not enough. The overall statistics collected during the tests can be found in Table 2 and Figure 5.

Figure 4. Comparison of different learning methods. Left chart reports the number of right answers after the combination of classical lecture and AR. Central charts are the answers after the sole use of AR. Right chart the correct answer after the lecture without AR.

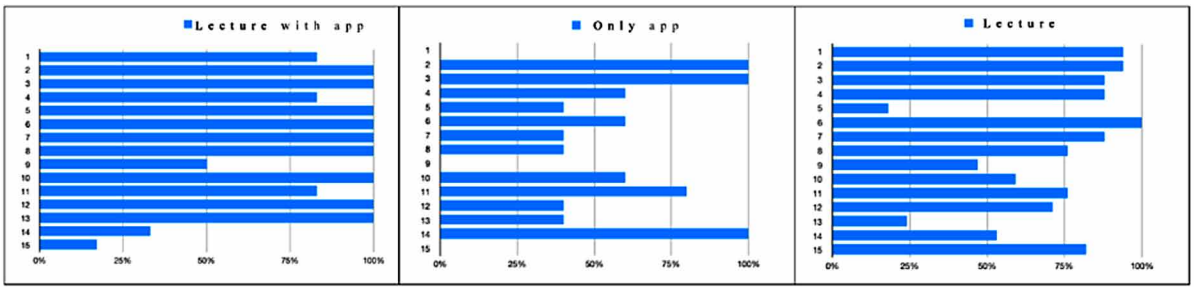
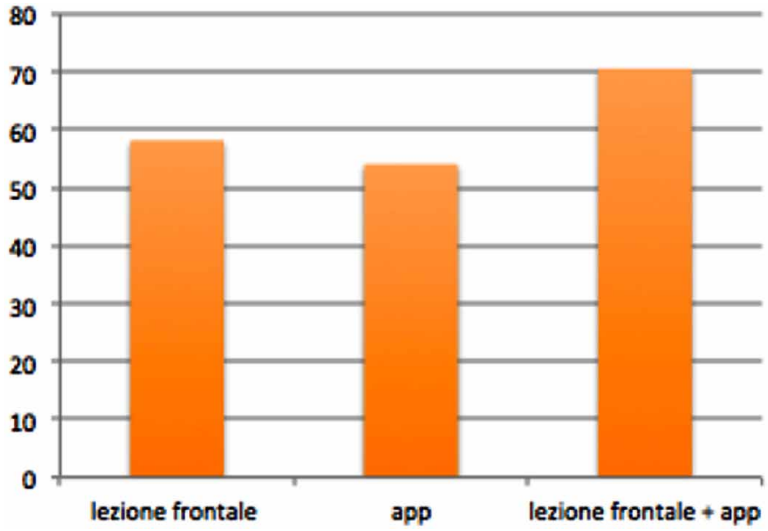


Table 2. Data final report. Comparison of all data collected with the different didactic approaches: classical lecture, only app and app plus lecture

	LICINI	RUBENS	Average
Lectures	70.11%	46.25%	58.18%
App	50.82%	57.33%	54.07%
Lectures+App	83.33%	57.85%	70.59%

Figure 5. Data final report



Summarizing the results obtained during the first step of experimental phase provided the following evaluations: the only frontal lesson is still a good means of transmitting contents and skills, valid for a satisfactory average learning response with a rate of 58.18%. The only use of the app is not a valid means of learning even if it is attractive and innovative with a rate of 54.07%. The combination of the frontal lesson and the app is a valid tool for learning, obtaining a rate of 70.59%.

Figure 6. Virtual Reality applied to the 3D reconstruction of the Roman theatre of Falerone: visualization of the informative tags inserted inside the reconstruction

The classical lecture still preserves its own value to spread and share the knowledge, since involves a bidirectional immersion among students and teacher. It is important the relation teaching-learning since involves several factors: emotional, experiential, relational, didactic, communicative, and psychological. Concerning the art being able to visit a museum, to know an archaeological site, to admire a monument constitutes an added value to the knowledge of the work, the technology helps this type of process by providing tools that involve the user, increasing the ability to obtain information, details, that would be difficult to find and consult in real time. The teaching experience and AR app increase the effectiveness of the learning process by giving scenarios increased with content that can be easily found in flexible and interconnected ways. The information that a teacher provides is then enhanced through a psychological and gestural involvement that cannot be transmitted by technology. On the other hand, the richness of connected information is mediated by versatile devices that create experiences in which the students find a response to methods that they are familiar with. The first data provided by this research leads to the conclusion of a mediated use between new technologies and traditional education. One cannot undertake innovative learning programs without validating their long-term efficiency. Analysing data it is clear that the didactic action has better value through the intervention of the teacher who succeeds in transmitting the contents in a more useful manner. The contribution of AR is enriching for a greater involvement of the students in the training activity, and demonstrates that increases the ability to learn, as shown by the increasing number of correct answers.

VR APPLICATION: THE ROMAN THEATRE OF FALERONE

The experience of reading the Roman theatre of Falerone reconstructed in 3D within the SmartMarca (Figure 6) application was proposed. The theatre contains not only charm as a place of entertainment, but also a direct testimony of Roman building capacity. The reconstruction represents both the unitary image of the entire artifact, and the descriptions of the various components of the monument and the relative precise definitions, in order to also provide concepts that can be used in the knowledge of similar architectural typologies.

All the Municipalities belonging to the District of Fermo (Provincial Capital in the Marche Region) have been the object of development of VR applications within the SmartMarca project. These applications are mainly aimed at reading the most significant urban and monumental places in the individual territories, to spread their knowledge. Among the various Municipalities in the area, the city of Falerone symbolically represents the added value that characterizes all the small and large towns of the Fermo area: keeping traces of the past that marks the historical and cultural value not only of the Marche but of the whole Italian territory. The Roman remains of the ancient city of Falerio Picenum date back to the 1st century A.C. when it was founded following an Augustan centuriation of the Tenna Valley.

This important testimony of the historical value of the territory has been the subject of a 3D VR reconstruction, inserted within the SmartMarca application.

The added value of the reconstructive hypothesis consists in having inserted the reading tags of the monument in its constitutive parts: architectural, structural and decorative. Therefore, the user, who can be any student or tourist, can know in detail the whole scenario of the theatre and learn about the functions of each single element: from the entrances (called vomitoria) to the subdivision of the seats for spectators, divided by census and political value. Figure 7 shows the view of the frontal scene and the lateral doors.

This detailed description also makes it possible to understand the functions and organization of the theatre's stage set-up, enriched by statues and decorations, which make the distinctive character of the theatre of Falerone. The statues dedicated to the goddess Ceres or Demeter, goddess of fertility and agriculture, declare the cultural nature of the territory mainly based on the cultivation of the fields and therefore linked to an agricultural tradition.

Figure 7. Visualization in Virtual Reality of the 3D model of the Theatre of Falerone: view of the front scene and side door

Figure 8. Students on a guided tour of the Roman remains of Urbisaglia (MC). Development of the second step of the educational research work: Visit to the remains of the temple, the amphitheatre and the theatre

Being able to observe these elements in detail through Virtual Reality also means having the time necessary to study carefully what is in front of you. Students can reflect and learn the elements necessary to implement the knowledge acquired with previous preparatory lessons for the virtual visit of the monument. So the advantage of the virtual visit to the monument is the time factor that allows the student to take advantage of the complete vision of the building in a more extended time frame and with a greater wealth of details. The information provided by the tags, directly related to the described element, help the student to visually focus the architectural part in question.

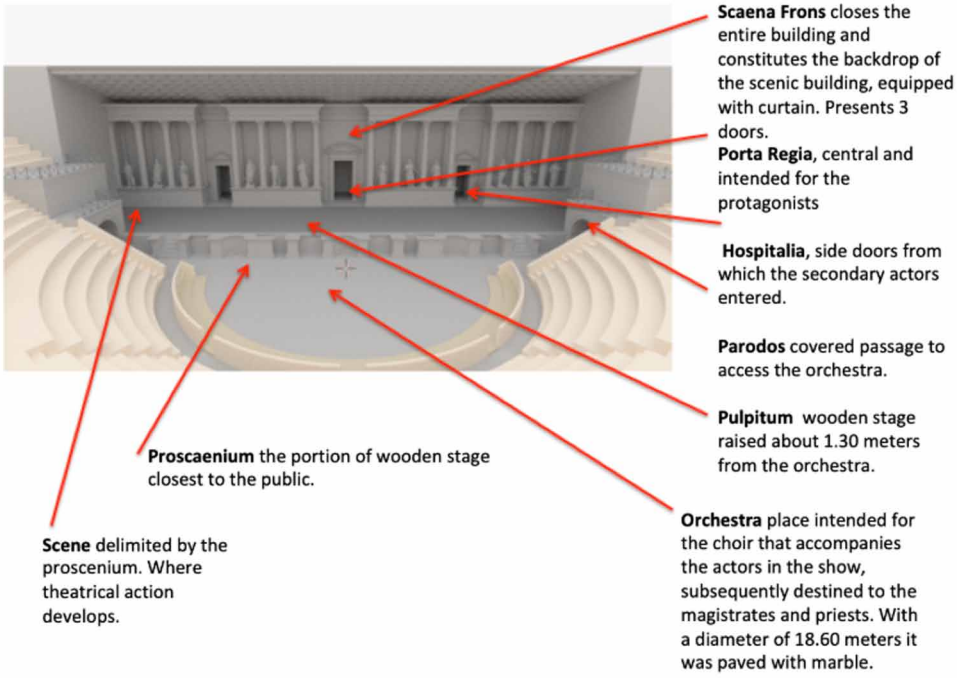
Didactic Methodology

Regarding the methodological analysis, the students of two first classes of upper secondary education were involved, respectively attending the Graphics and Communication Course (1AGR) and the Construction Environment and Territory Course (1ACAT). The school program of the discipline technologies and techniques of graphic representation involves the introduction of the History of architecture and art from the period from its origins to the late Roman period. Within the topics regarding Roman architecture, students are shown the major public buildings expressing classical Greek and Roman culture. Among these, is the theatre that represents, for its functions and its architectural typology, the expression of excellence of these civilizations founding the Mediterranean culture.

The first step of the didactic work concerned the traditional lesson in class in which the students learned the fundamental elements of the architectural and constructive culture of the Romans and the distributive and functional characteristics of the Roman theatre. The explanations have been enriched not only by the content of the textbook, but also by projections of images of remains of Roman theatres, taken from websites.

The second step has developed through a direct experience of visiting the archaeological park of Urbisaglia, in the province of Macerata. The area still shows evident and therefore easily legible traces of the ancient Roman settlement, of which the remains of the theatre, the amphitheatre and a temple remain well preserved in their characteristics. The site contains the most important peculiarities of a Roman urban intervention, for which it represents a valid instrument of knowledge of this historical and architectural testimony. As shown in Figure 8, during the visit, the students were invited to carefully read the architectural and distribution elements of the building.

Figure 9. Teaching content developed by the teacher, inserted in the tags of the SmartMarca application, related to the theatre of Falerone



The third step took place again in the classroom through the use of the SmartMarca application that contains the 3D reconstruction of the Roman theatre of Falerone, coeval with the Urbisaglia theatre. The contents of the tags have been developed by the teacher and highlighted in figure 9. Each text contains descriptive elements useful for reading a Roman theatre in its distinctive features, so the educational validity of the application is guaranteed by the formative correspondence of the information to be transmitted.

A check was therefore proposed aimed at collecting data about the knowledge acquired from the educational path developed up to now, concluding the activity with the study of the contents inserted in the SmartMarca application.

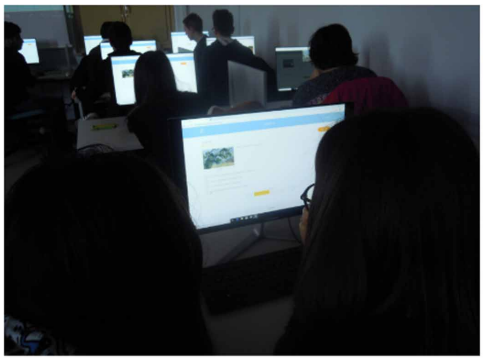
The two class groups, up to this stage, carried out the work in a homogeneous and equivalent way, while in the next step they were divided: the first group of students was asked to prepare the verification by studying the contents of the application in advance at home, the second group was shown the content only shortly before the verification.

Figure 10 describes the work steps of the two class groups. First step: frontal lecture in class both 1ACAT and 1AGR. Second step: guided tour of archaeological park in Urbisaglia, both 1ACAT and 1AGR. Third step: use of the app with VR of the Teatro di Falerone, the 1ACAT class assigned study at home while the 1AGR class study in the classroom before verification. Fourth step: online verification with the Socrative program.

In the fourth step the students were engaged in the final verification of the course (Figure 11). The verification, administered to students through the Socrative web-based platform, contains multiple-choice questions. The requests contained in the questionnaire are substantially of 2 types: on the nomenclature

Figure 10. Description of the work steps of the two class groups

Figure 11. Students engaged in class in Socrative web-based verification



of the parts of the Roman theater (applicable to any theater in general) and on the historical, architectural and decorative features of the theater of Falerone, as Table 5 shows.

The answers collected highlighted the following information:

- definitions of the constituent parts of the theater have been acquired;
- the functions of the elements of the theater have been understood;
- the materials and construction techniques of the theater are known.

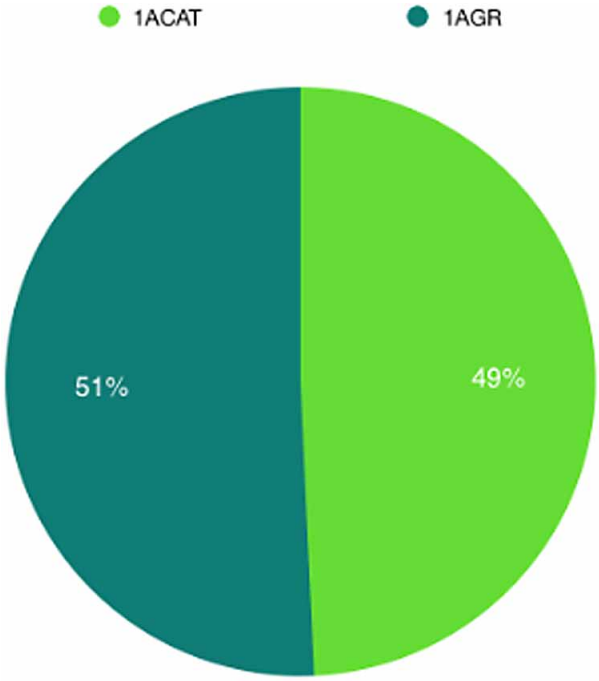
Data Analysis and Discussion

The results achieved in overall terms by the two groups are substantially and globally homogeneous, with a slight positive deviation for the class 1AGR group, as shown in figure 12.

From the analysis of the single questions it results that the 1AGR group correctly answered in greater percentage to the requests related to the information provided by the app regarding dates and numerical values that are easily memorized, if the information source has been recently consulted.

The 1ACAT group, which did not consult the app before the test but studied the content at home, instead memorized the technical aspect of the division of the rooms and the materials used and then responded correctly to the related questions.

Figure 12. Rate of correct answers for each class group



Looking at figure 13, the 1AGR class has a higher percentage of correct answers to notional questions, the 1ACAT class has a higher percentage of correct answers to technical questions

It should be emphasized that the first group belongs to the Graphics and Communication Course, therefore the students are particularly predisposed for training and aptitude to use multimedia means and to grasp the fundamental elements under the digital profile.

The second group belongs to the Course Construction Environment Territory, therefore particularly sensitive to the technological and structural aspect proposed in the analysis of the monumental artifact.

However, the average obtained by the two groups, 66.48% the first and 68.48% the second, confirm the effectiveness of the use of VR combined with traditional teaching systems, in the didactic field . These value can be extracted by Figure 14.

The following elements of validation of the analysis are noted:

- Having carried out a common path of acquisition of elements preparatory to the reading of the architectural artefact of the theater constituted a suitable element to validate the possession of the skills necessary for the didactically profitable use of the digital instrument;
- Both groups have demonstrated that they have reached more than sufficient knowledge of the subject in question;
- THE app proved to be a useful compendium of theoretical and practical knowledge;
- the consultation of the information provided by the app has highlighted the particular peculiarities of the two class groups, through the diversification of the correct answers provided.

Figure 13. Comparative table of the correct answers provided by the two class groups

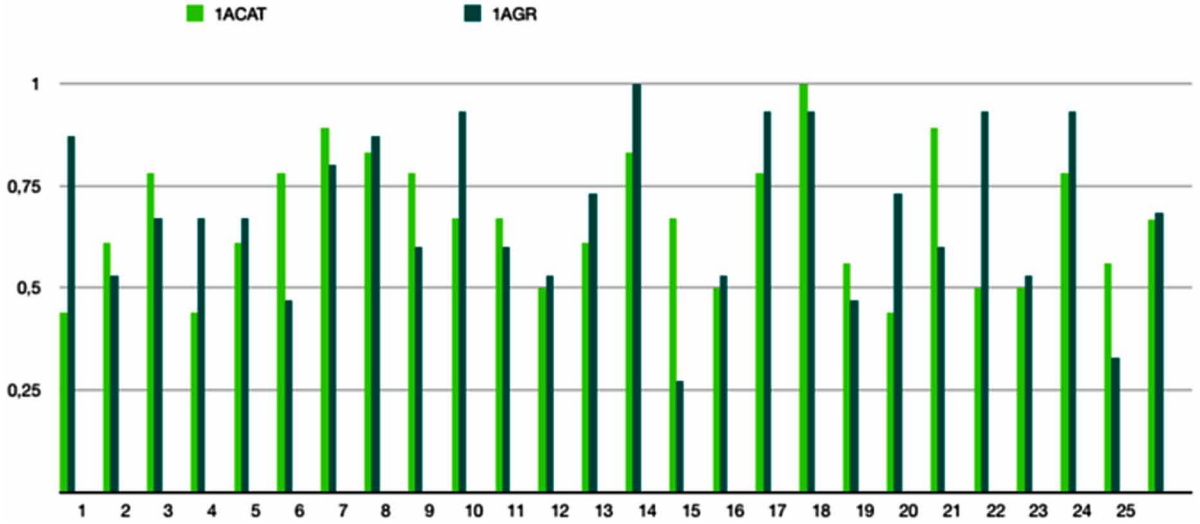
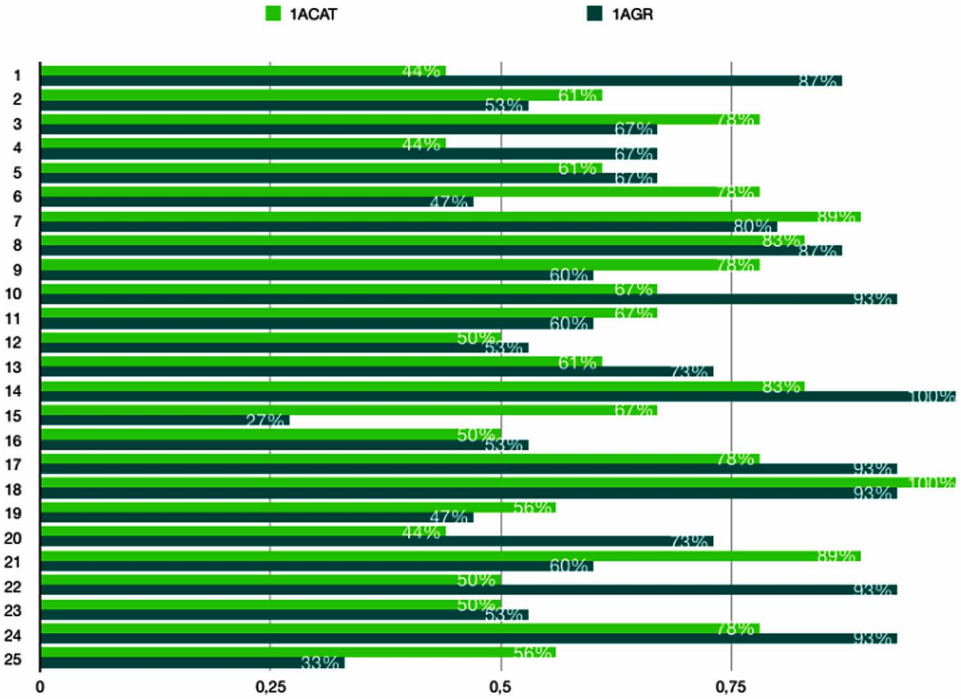


Figure 14. The results achieved by both class groups averaging stand at over 50%, confirming the more than sufficient acquisition of the proposed contents



To add the particular interest shown by the students, through the active involvement shown during the entire educational path proposed. The diversification of the methodologies adopted, from the traditional

frontal lesson accompanied by the direct visit of the site, followed by learning with the use of digital technology, has produced an interesting didactic result, which will now be verified in the long term.

For the teacher the development of the content of the app, its use within the training course offered to the students and the following proof has constituted an interesting methodological study.

In tracing the founding points of the subject matter, to carry out the insertion in the various tags, the teacher has identified the so-called minimum disciplinary objectives necessary for the students to develop the skills and knowledge that can be spent in a transversal way.

The verification methodology allowed a comparison of results between the two classes, highlighting the peculiarities of each one as evidence of the value of teaching based on students and therefore on individual skills.

It remains to be seen how, in the long term, it is possible to create similar methodological situations declined on the different topics and on the different disciplines.

AUGMENTED REALITY AND VIRTUAL REALITY: A COMPARISON IN THE DIDACTIC FIELD

The learning experiences conducted using AR and VR have highlighted the potential and limitations of individual technologies. Despite having peculiarities and different methods of presentation and use, the two technologies have been tested in the educational field to verify benefits, using the content of the applications related to the SmartMarca Project. In particular, the application of reading the "Adorazione dei Pastori" painting by Rubens, was used to test the AR, while for the VR, the vision of the Piazza del Popolo of Fermo was proposed.

The study carried out in this research phase, aims to verify and compare the greater correspondence of the two tools in terms of ease of use, the real capacity of transmission of content and student involvement.

Methodology

The activity carried out was organized with the following methodology (Figure 15):

- use of AR or VR system and reading the real image with the image proposed by the device;
- use of the device and immersion in the content proposed in AR and VR mode to understand the data to be tested;
- filling out the questionnaire prepared to gather information and elements for evaluation and comparison of the two technologies.

The students, after viewing the Rubens painting, used their smartphones to access the contents of the app in AR mode (Figure 16). The reading of the tags present in the painting was carried out in total autonomy by the students. Once this first phase was completed, the questionnaire was completed.

In reading Piazza del Popolo, the students wore Oculos visors where they had already inserted their smartphones (Figure 17). After selecting the section relating to the city of Fermo, they visited the Piazza in VR. At the end of the 360° view of the entire urban system, they completed the online questionnaire.

Figure 15. Methodology of study for the comparison of the two digital systems: vision of the real image, use of the device, compilation of questionnaire, data collection and analysis

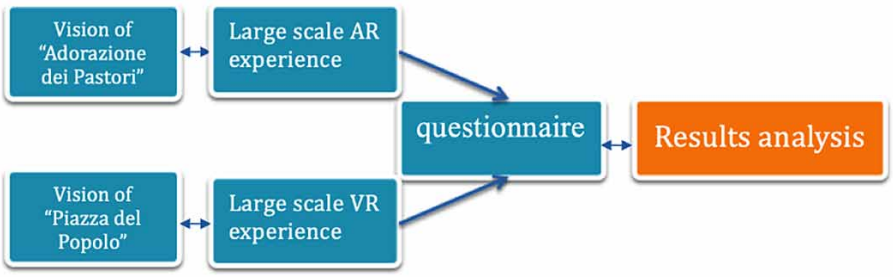


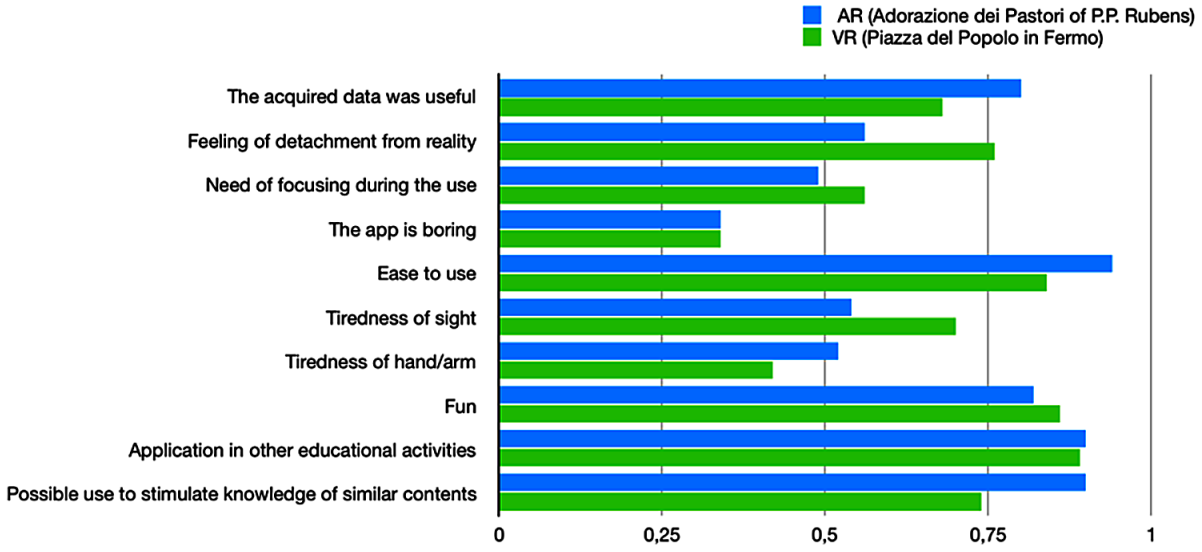
Figure 16. Use of Augmented Reality in front of the "Adorazione dei Pastori" of P.P. Rubens

Figure 17. Students while are testing VR applied to the 360° view of the "Piazza del popolo" in Fermo

Data Analysis

At the end of the experience of using devices with AR and VR applications, the online questionnaire proposed to the students was structured in two sections: one aimed at data collection related to the AR application on the painting by Rubens, the other to the collection data concerning the 360° visit applica-

Figure 18. Comparative histogram of the answers relating to table 7



tion of the Piazza del Popolo. The questions tested different areas, as Table 6 in appendix 1, shows. The five-level Likert scale was used (1- not at all in agreement, 5- very much in agreement).

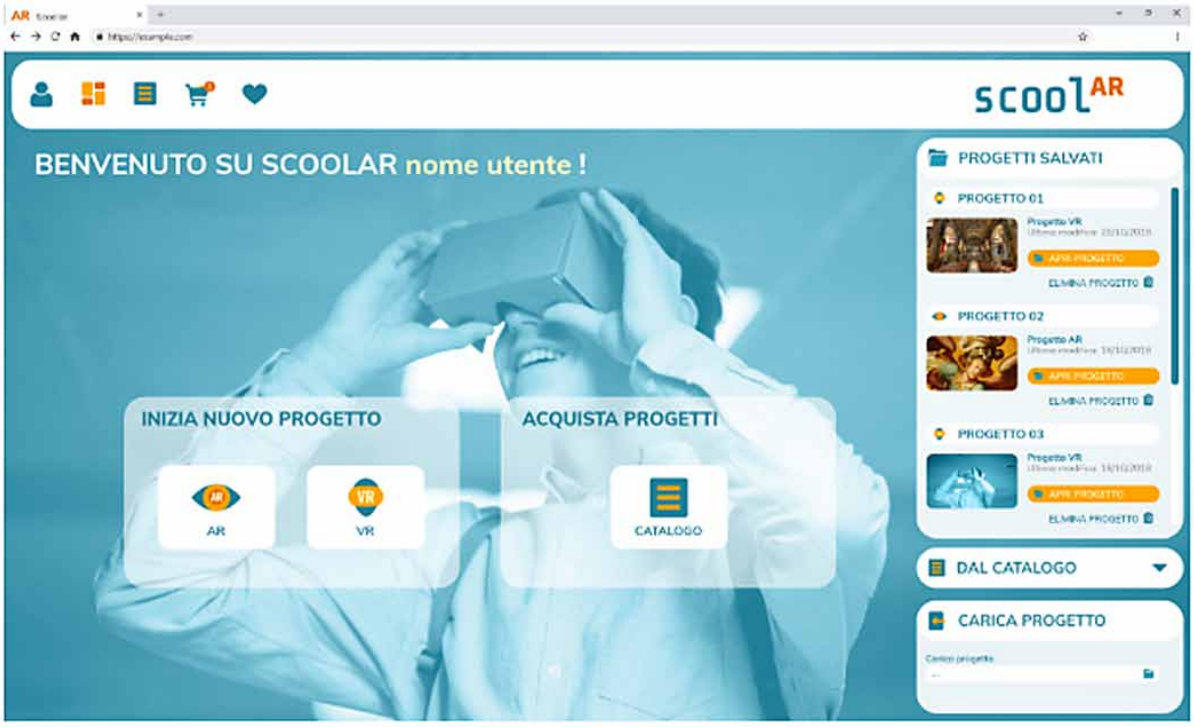
To facilitate the reading of the data the questions have been grouped by type, so as to allow a comparative view of the results. The percentages (Table 7, in appendix 1) represent the favorable answers. In figure 18, it is possible to verify the results compared, relating to the use of AR and VR.

CONCLUSION AND FUTURE RESEARCH DIRECTIONS

Within the framework of Smart Marca project, this chapter focuses on assessing the potential of AR/VR applications specifically designed for Cultural Heritage. More specifically, tests have been conducted on AR experience upon different paintings, while VR was developed on an ancient amphitheatre. Tests were made on two classrooms of teenagers to whom different learning approaches served as an evaluation method about the effectiveness of using these technologies for the education process. Analyzing the results obtained comparing AR and VR technologies and presented in Table 7 (in appendix 1), the following conclusions can be drawn:

- the AR system:
  - has greater ability to transmit information and content and their relative acquisition;
  - determines less sensation of detachment from reality;
  - needs less concentration during use;
  - it is easier to use and less tiring to look at;
  - is recommended for use in other areas and not only for teaching purposes.
- The VR system:
  - less fatigue in the hand / arm system;
  - creates more fun;
  - can be proposed for further educational uses.

Figure 19. A screenshot of SchoolAR application



However, both systems and their applications are not bored during their use.

It can be deduced that VR, despite being more widespread and known in the field of video games and non-didactic applications, has less potential for continuous use as it greatly strains the eyes and creates a greater detachment from reality. The use of the viewer also reduces its ease of use and in any case requires greater concentration on the part of the student. The AR in this case is easier to use, since it does not require any particular use devices. The constant relationship with reality facilitates concentration during use. The view is in fact stimulated by reading the data superimposed, creating a greater involvement of the student in understanding them. Overall, it therefore constitutes a methodology that is potentially more appropriate for application in the didactic and informative field, thanks to its characteristics of use of the device and transmission of content. What finally emerged from the study is that, despite technology is able to convey ”disposable” information, it is far from stimulating the self reworking by the students, which still remains entrusted on the teacher role.

In the future, our proposal will be to create a platform called schoolAR for the creation of an educational content. In fact, it is well known that there is the necessity of developing new tools to enable users to become producers of contents of AR/VR experiences, since up to now there no exists a platform specifically designed for an agile creation, even for not skilled programmers. The intent is to propose a cooperative platform between teachers and students, which allows the use of innovative technologies (AR and VR) to stimulate student learning. After access, the user will be able to access a series of sections that will give the opportunity to continue the projects started, create new projects or consult the catalog of available content. Figure 19 shows the home screenshot of SchoolAR, an on-going project upon which our research group will concentrate the efforts. Another important aspect that will be investigated in the

upcoming future is the long term effects of AR/VR in education. By submitting further test to the students, it will be interesting to uncover how, and if, technologies have real effects on knowledge retention.

ACKNOWLEDGMENT

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KEY TERMS AND DEFINITIONS

Depth knowledge: Gaining information and data that become the own heritage of a student.

Learning by searching: The capability of a student to learn directly with a close research experience.

Learning needs: The necessity that every student might have during a learning experience.

Long term effects: Capability of using the gained competences over time.

Minimum disciplinary objectives: Knowledge of basics arguments of a discipline, compulsory for understand the fundamentals.

Training activity: The process of transmitting knowledge, through didactic strategies.

Transversal skills: The capability of a student to interpret information and rework it by using competences gained in other fields.

ENDNOTES

1 https://www.aurasma.com/

2 https://nearpod.com/

3 https://edu.google.com/products/vr-ar/expeditions/?modal_active=none

[4] https://vr.google.com/cardboard/
[5] https://luden.io/incell/
[6] http://w2.vatican.va/
[7] http://www.marcafermana.it/it/Smart-Marca/

APPENDIX 1

Table 3. Survey administered to students upon completion of the teaching experience on "Adorazione dei Pastori'" di P.P. Rubens

ADORAZIONE DEI PASTORI		
CODE	QUESTION	ANSWERS
Q1	What are the elements present in the mantle of the Madonna that recall the late-ancient Christian tradition?	4 OPTIONS 1 RIGHT
Q2	In representing the face of the Madonna, Rubens was inspired by ...	4 OPTIONS 1 RIGHT
Q3	The sense of vitality of the Madonna's face comes ...	4 OPTIONS 1 RIGHT
Q4	The open mouth of the Madonna alludes	4 OPTIONS 1 RIGHT
Q5	The hands of the Virgin are ...	4 OPTIONS 1 RIGHT
Q6	The hands of the Virgin move for ...	4 OPTIONS 1 RIGHT
Q7	The hands of the Madonna ...	4 OPTIONS 1 RIGHT
Q8	The Child is the protagonist of the painting. The painter paints him ...	4 OPTIONS 1 RIGHT
Q9	The light that comes from the Baby Jesus illuminates the face of the Virgin and of the other characters ...	4 OPTIONS 1 RIGHT
Q10	The straw on which the Baby Jesus is laid, full of light, seems to be burning while ...	4 OPTIONS 1 RIGHT
Q11	The figure of St. Joseph is confused with the colors of the background of the painting, because ...	4 OPTIONS 1 RIGHT
Q12	The landscape on the background of the painting and the figure of Saint Joseph ...	4 OPTIONS 1 RIGHT
Q13	The shepherd with sheepskin is poorly dressed, leaning on a stick and has the face of an old man. It is confused with the bottom of the painting and is placed in the extreme part of the painting. The Rubens wanted ...	4 OPTIONS 1 RIGHT
Q14	The elderly pastor puts his hand on his forehead ...	4 OPTIONS 1 RIGHT
Q15	The red of the young kneeling shepherd's tunic represents ...	4 OPTIONS 1 RIGHT
Q16	The pose of the kneeling shepherd recalls for the Rubens ...	4 OPTIONS 1 RIGHT
Q17	The old woman with raised hands represents ...	4 OPTIONS 1 RIGHT
Q18	In realizing the character of the old woman, Rubens imitates a great master of painting ...	4 OPTIONS 1 RIGHT
Q19	The four angels that accompany the shepherds are positioned high up in the canvas and dominate the scene. The composition allows to appreciate ...	4 OPTIONS 1 RIGHT
Q20	The composition of the angels made by Rubens testifies to the passion of Rubens for ...	4 OPTIONS 1 RIGHT
Q21	The hands of the different characters in the painting represent ...	4 OPTIONS 1 RIGHT
Q22	Among the different characters which seems to be a stranger to the composition ...	4 OPTIONS 1 RIGHT
Q23	The painting was intended for the Oratory of the Church of ...	4 OPTIONS 1 RIGHT

Table 4. Survey administered to students upon completion of the teaching experience on Osvaldo Licini

PAESAGGIO		
CODE	QUESTION	ANSWERS
Q1	The “Paesaggio’” by Osvaldo Licini is donated to the Municipality of Monte Vidon Corrado in 2015 in memory ...	4 OPTIONS 1 RIGHT
Q2	The painting the “Paesaggio” represents a view ...	4 OPTIONS 1 RIGHT
Q3	The birthplace of Osvaldo Licini is ...	4 OPTIONS 1 RIGHT
Q4	The artist usually paints “en plein air”, that is ...	4 OPTIONS 1 RIGHT
Q5	The rich colors of the painting recalls the works of ...	4 OPTIONS 1 RIGHT
Q6	The clouds seem to transform ...	4 OPTIONS 1 RIGHT
Q7	The hills and the sky converse with each other ...	4 OPTIONS 1 RIGHT
Q8	The leafy tree in the foreground ...	4 OPTIONS 1 RIGHT
Q9	The small farmhouse ...	4 OPTIONS 1 RIGHT
Q10	The sign on the canvas ...	4 OPTIONS 1 RIGHT
Q11	The line has the purpose ...	4 OPTIONS 1 RIGHT
Q12	The painting the “Paesaggio” is made by the artist ...	4 OPTIONS 1 RIGHT

Table 5. Survey questions given to students at the end of the didactic experience on the Theatre of Falerone

ROMAN THEATER OF FALERONE		
CODE	QUESTION	ANSWERS
Q1	Which was the name of the ancient Roman city of Falerone	4 OPTIONS 1 RIGHT
Q2	Unlike the Greek theater, the Roman theater ...	4 OPTIONS 1 RIGHT
Q3	The construction technique is that ...	4 OPTIONS 1 RIGHT
Q4	The place destined to the choir and subsequently destined to the magistrates and priests takes the name of ...	4 OPTIONS 1 RIGHT
Q5	The main place for spectators is called ...	4 OPTIONS 1 RIGHT
Q6	The service areas under the Cavea also have the function ...	4 OPTIONS 1 RIGHT
Q7	How many spectators could hold the theater of Falerone	4 OPTIONS 1 RIGHT
Q8	The Parados in the Roman theater is ...	4 OPTIONS 1 RIGHT
Q9	Secondary actors could enter the stage ...	4 OPTIONS 1 RIGHT
Q10	During the II century D.C., in the period of Antonino Pio, the theater of Falerone	4 OPTIONS 1 RIGHT
Q11	The Porta Regia is the entrance ...	4 OPTIONS 1 RIGHT
Q12	The stage housed dedicated statues ...	4 OPTIONS 1 RIGHT
Q13	The steps that hosted the audience and the orchestra were covered ...	4 OPTIONS 1 RIGHT
Q14	How high is the Pulpitum compared to the Orchestra ...	4 OPTIONS 1 RIGHT
Q15	With what material the Pulpitum is made	4 OPTIONS 1 RIGHT
Q16	The Roman city of Falerone was born ...	4 OPTIONS 1 RIGHT
Q17	The Vomitoria are...	4 OPTIONS 1 RIGHT
Q18	The theater has a semicircular shape ...	4 OPTIONS 1 RIGHT
Q19	The Roman theater has an external portico ...	TRUE/FALSE
Q20	The summa cavea was intended for magistrates and officials	TRUE/FALSE
Q21	The ima cavea was intended for women and the plebs	TRUE/FALSE
Q22	The backdrop of the theater scene has three doors	TRUE/FALSE
Q23	The velarium in the theater was used ...	4 OPTIONS 1 RIGHT
Q24	The actors in ancient Rome were only men	TRUE/FALSE
Q25	Actors in the Roman period used the buskins ...	4 OPTIONS 1 RIGHT

Table 6. Questions included in the online questionnaire to the students at the end of the experiences in AR and VR mode

"ADORAZIONE DEI PASTORI" – AR EXPERIENCE	
CODE	QUESTION
A1	Have you understood the explanation of the individual parts of the picture
A2	Do you think this method is useful for explaining a painting
A3	After using this app do you think you better know the Rubens painting
A4	Do you feel detached from reality when you use the app
A5	Do you feel immersed in the painting
A6	Are the explanations in the tags ease to read
A7	Do you think the use of this application requires a lot of concentration
A8	Do you think the app is boring
A9	Do you think the app is ease to use
A10	Your arm or hand got tired while you were using the app
A11	Do your sight get tired while using the app
A12	Do you enjoy using the app
A13	Would you like to read another picture with this system
A14	Would you like to read pictures of school books with this system
A15	Did you already know AR
"PIAZZA DEL POPOLO"- VR EXPERIENCE	
B1	Did you think this method helps you to learn more about place
B2	Did images help you see details
B3	Do you feel detached from reality when you use the app
B4	In your opinion, does using this application require a lot of concentration
B5	Do you think the app is boring
B6	Do you think the app is ease to use
B7	Your arm or hand got tired while you were using the app
B8	Do your sight get tired while using the app
B9	Is using cardboard/oculos uncomfortable
B10	In your opinion, can Virtual Reality be applied in educational activities
B11	Did you already know VR
B12	Do you enjoy using the app
B13	Do you prefer visit a place with the app rather than travel
B14	Do you think that using the app encourages the desire to visit a place

Table 7. Percentages of favorable answers to the questions asked in the online questionnaire, grouped together by typological classes

QUESTION	AR use: "Adorazione dei Pastori" by P.P. Rubens	VR use: "Piazza del Popolo" in Fermo
The acquired data was useful	**80%**	**68%**
Feeling of detachment from reality	**56%**	**76%**
Need of focusing during the use	**49%**	**56%**
The app is boring	**34%**	**34%**
Ease to use	**94%**	**84%**
Tiredness of sight	**54%**	**70%**
Tiredness of hand/arm	**52%**	**42%**
Fun	**82%**	**86%**
Application in other educational activities	**90%**	**89%**
Possible use to stimulate knowledge of similar contents	**90%**	**74%**