Teaching Cultural Heritage using Mobile Augmented Reality

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TEACHING OUR CULTURAL HERITAGE USING MOBILE AUGMENTED REALITY

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The relationship between augmented reality, mobile learning, gamification and non-formal education methods provide a great potential. The AR-CIMUVE Augmented Reality for the Walled Cities of the Veneto is an original project in collaboration with Italia Nostra and other associations which deal with transmitting our cultural heritage and which teach primary and middle school children the cultural and historical importance of the Veneto's and the surrounding territories' walled cities. In this learning experience students will explore how our environment has developed across the ages using the mobile devices with the technical back-up of the AR App. This will allow them to see maps, examine data, 3D models and will enable them to test and improve their skills. From a pedagogical and educational point of view the emphasis is on a constructivist social-cultural approach which helps students to become active citizens more aware of their historical identity.

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1 Introduction: Augmented Reality

In recent years thanks to the rapid development of mobile technology we have at our disposal portable devices which combine the great ability to manipulate data along with many sensors which allow us to interact with the environment. Augmented Reality technology allow us to overlap our sensory perception of reality with one generated by a fixed or mobile device. Some mobile technologies have an in-built operative system for example Google Glasses or Microsoft Hololens, others include software which can be downloaded on the smartphones as simple Apps. In the most common understanding of the term Augmented Reality provides a virtual layer of contextual information, pictures or 3D models which interact with environments or real objects. AR takes place within a continuum lying between two opposite poles: the real environment and the virtual environment (Milgram *et al.*, 1994) and the applications within this interval are part of mixed reality. There are two types of AR 1) location-aware 2) vision-based. Location-aware AR presents artefacts to learners as they move with a GPS-enabled mobile device. The media augment the physical environment with information relevant to the place. Vision-based AR presents digital media to learners after they point the camera in their mobile device at an object (Dunleavy & Dede, 2014). Thanks to the ability to link the virtual with the real, the potential of augmented reality in the field of education has increasingly attracted the attention of researchers who recognize in this promising pedagogical instrument a fundamental role in the school of the future. (Dede, 2008). There are already many interesting educational applications of Augmented Reality available in particular for science to use in and outside classroom such as "Anatomy 4D" (human anatomy), "Science AR" (science poster), "Elements 4D" (chemistry), but still few studies on the real value of this technology and reliable models (Pribeanu, Balog & Iordache, 2016).

2 How can augmented reality mobile learning be adapted to a teaching methodology?

In the history of the educational use of technology one has always been convinced that this method improves the teaching-learning process. However recent in-depth studies based on hundreds of tests in the past 20 years (Hattie, 2009; Tamim, 2011) appear to demonstrate that technology in itself does not guarantee a significant improvement (Rushby & Seabrook, 2008). In fact, they seem to have a neutral or average impact and in certain cases even negative effects due to overloading of the cognitive process, a problem underlined by Cognitive Load Theory (Sweller *et al.*, 1998). All the research papers point to the fact that the most important measure of success in the use of technology in

teaching is the choice of adequate methodologies appropriate to the context in which they are to be used (Kirschner *et al.*, 2006; Calvani, 2014). From this point of view mobile devices like smartphones are considered more disruptive than the traditional devices used in school (i.e. Computer, Smartboards, etc.) principally because the students always carry them with them and use them in informal daily life contexts. The teaching strategies which include the use of mobile devices have to take into account the setting of such a complex and transversal learning experience. In fact, in the experimental development of mobile learning one come identify three main phases characterized by different focuses (Sharples, 2006). The first is the use of portable devices in class, the second on activities which are able to support a structured learning project outside the classroom, the third focuses on self-directed and just-in-time students' learning processes (Pachler, Bachmair & Cook, 2013). There are in fact many experimentations to create augmented environment for active learning that could be also brought out of school (Zimmermann, 2013; Perez *et al.*, 2014; Miglino *et al.*, 2014).

A first phase was characterised by research on finding the most suitable device to be used in the classroom contexts and in this way there has been attempt to take advantage of the specific affordance: eBooks, iPads are common examples of this. The second phase was characterized by a shift of attention from out-of-the-classroom learning to the potential use of mobile devices to support typical non-formal learning experiences for example visits to the museum and similar activities. In the third phase, which is the present phase, we tend to take into account the mobility of the student and his independent learning in independent informal learning experience (Coyle *et al.*, 2006). Research on the teaching potential of AR is now going through this third phase in which mobile learning is slowly being transformed into Augmented Reality Mobile Learning. The principle tray of Mobile Learning it is that it allows a situated learning experience (Wenger & Lave, 1991) mediated by specific technology. The measuring stick is essentially that of Vygotsky according to whom the human beings learn about the world around them through instruments and artefacts which increase our "Proximal Development Zone".

The potential of AR is so great that its transformations from mobile to AR is not only a quantity but also of quality. In fact, the reality which we re-interpret through a continual process of attribution and through the instruments which mediate our relationship with reality change proportionally to the quality of the interaction given by the affordance of the instrument itself. AR applications can support new learning paradigms (Chen & Wang, 2008) filling the gap between the theory and practice using constructive activities. It is for these reason that the choice setting and the teacher's role are so important: the experiences with ARML can certainly be used within a traditional teaching

setting in the classroom for example but in this way they would lose much of their great potential (Auld & Johnson, 2015). It is necessary to come up with a new curriculum to allow the student to integrate informal learning through ARML technology and which experiments outside the school context with informal learning processes. Teachers need to encourage these instances of meaningful learning (Jonassen, 2008) providing students with a conceptual means of judging their ARML experiences within the prospect of self-regulated learning and life-long learning. An educational approach which contains all of these characteristic is that of the Project Based Learning (PBL) (Strobel & van Barneveld, 2009; Walker & Leary, 2009; Thomas, 2000) which considers these examples of informal learning not as distinct elements from the social but an integral part of them because of the social and active way of constructing knowledge (Engeström *et al.*, 1999; Sharples, 2014; Ranieri & Pieri, 2014).

3 ARML and Cultural Heritage: origins of AR-Walled Cities of Veneto project

Looking back at the last fifteen years one can name several examples of software which use Virtual Reality to explore and reproduce artefacts and ancient sites which in modern times present themselves in a totally different form or which are today totally inexistent (for example the Virtual Hagia Sophia or the Ancient Malacca Project or even Virtual Pompeii). This kind of software bears in mind specific aims (Noh *et al.*, 2009):

- to document constructions an historical object in order to reconstruct them in case of destruction.
- to create resources for the promotion of cultural and historical studies.
- to reconstruct historical monuments or parts which no longer exist.
- to visualize scenes from difficult or practically impossible angles.
- to interact with objects without the risk of damage.
- to promote tourism and virtual exhibitions.

There are available today virtual reproductions of historical sites based on software such as Open Virtual Worlds which allow the creation of environments that permit a virtual interaction with other users and interesting educational outcomes, for example the virtual reconstruction of St. Andrew's Cathedral in Scotland (Kennedy *et al.*, 2013). We haven't the same quantity of examples as far as AR for the cultural heritage is concerned. However as mentioned previously there have been advances in this field in recent years. This software has similar aims as that which uses virtual reality but its use is best seen in educational and didactic situations because of the affordance aspect of the AR mentioned beforehand. Let us now move on to examine some particularly

significant examples. Archeoguide was one of the most ambitious projects in this field (Vlahakis *et al.*, 2001). This used to be a client-server application. The server aspect contained a series of information on three-dimensional sites and models linked to a specific geographical place. The client aspect was made up of a laptop along with a specific software installation, a GPS, a head mounted display with a specially mounted camera in front. Thanks to the GPS data the client could download this contextual information including the 3D models. These models featured the structures as they would have appeared soon after completion and could be accurately placed on real life images taken by a camera which, combined to AR, could then be presented to the user by means of the head mounted display. This portable system, which seems cumbersome today, was necessary because, in 2001, devices such as present smartphones endowed with the necessary calculation potential, were non-existent. In the first decade of the new millennium similar projects were devised but they all had to face the problem of reduced portability, of inadequate mobile operative systems and hardware, as example project PRISMA till 2008 (Fritz *et al.*, 2005). Taking a leap in time and in technology we come to the year 2011 when the Region of Apulia presented the application for Android and iOS "Puglia Reality+". This application relies on operative systems, sensors and the power of the new smartphones to provide an AR experience at various levels. Visiting various cities in Apulia you have at your disposal an AR which taking advantage of the smartphone's camera and GPS manages to place virtual labels on real images in an AR visible on screen. The labels are interactive and when selected can provide photographs and information on the monument or the structure selected. If you visit one of the archeological sites where this option is available, the application is able to superimpose 3D models on the real things which allows the visitors to see the structure as it was originally intended thus giving him a tour of the mixed reality presented to him on the screen. The French company GMT Éditions, developed in 2014 a framework called Izzyguide 3D (de Bideran & Fraysse, 2015), which uses the same kind of technology as Puglia Reality+, but is more advanced, allows a more interactive experience for the user and a richer media and content. From this framework are derived Poitiers 3D and Avignon 3D, applications that allow you to follow a guided tour to the respective cities, displaying the evolution of the same place through the centuries by the maps (without geolocation) and through mixed reality. These applications, in addition to the information accessible from the menu, allow you to view interviews with experts and listen to audio-guide style information within the virtual tour. Only the 3D Avignon application, the most advanced of the two, also incorporates small interactive games.

These are the main experiences we were looking at by designing AR-

CIMUVE: mobile augmented/mixed reality applications, that can be used in site, in situation. Unfortunately, none of these is based on a solid pedagogical thinking. From this point of view, we believe that the project more in tune with our principles is the one of Chang *et al.* (2015) on the Sense of Place (SOP), even while using a different approach to the app interface. With SOP the authors intend the combination of feelings of attachment, dependence, concern, identity, and belonging that people develop regarding a place. Their study are based on the synergy between the framework of the Human - Computer - Context - Interaction (HCCI) (Greeno, Collins, & Resnick, 1996) and the strategy of Historical - Geo - Context - Embedded - Visiting (HGCEV) to conduct the visitor to reach the higher level of SOP through the following steps: to find out the past geographical and historical information about the heritage site; to Establish its geographical and historical context; when visitors visit the heritage site, the context allows them to feel interested in and interact with the heritage site, and further to establish the interaction among visitors, the heritage site itself, and the geographical and historical context of the heritage site.

The AR-CIMUVE "Walled Cities of the Veneto" project aims at students of primary and secondary schools once to recreate through a mobile AR application all the important characteristics of the Veneto's walled cities. Characteristics which are either difficult to see or not very clear. In order to encourage an innovative approach to learning about the past the design of the app is the result of a careful dialogue between educational technology experts of the FiSPPA Department University of Padua and cultural Heritage experts of the Italia Nostra association and the "Quartiere Attivo" association of Verona. The principal aims of the application are as follows:

1. The respect of the pedagogical principle and educational aims of AMRL
2. To stay within the pedagogical framework of our cultural heritage
3. The fact that it is simple to use and encourages a great amount of interactivity with the user
4. The content coincides exactly with a tour of the actual site
5. Students can provide feedback of what they have learned.
6. A variety of practical activities which encourages interaction between children and the cultural educator.

These aims transcend the applications described above but also share some of their characteristics. Here are some of the technical characteristics which are being implemented in the application:

- Client-server model: as in Archeoguide allows the application to download material and information from the server and to update it according to the GPS location.

- To enable one to visualize the present day structures and places as they were at the time of their construction thanks to superimposed 3D models through AR technology, as in Poitiers 3D and Avignon 3D.
- Historical and actual Maps with POIs as in Avignon 3D.
- Specifically geolocated and interactive AR tags as in the "Puglia Reality+".
- Some 3D interactive models of, for example, siege machines.
- Interactive quizzes, treasure hunts and mazes.
- Connection between the various devices thanks to social functions which allow the participants to share ideas and promote teamwork.
- Effective mixed reality through the Google Cardboard compatibility: better understanding thanks to immersive experience.

One hope that this application when integrated with projects or appropriate educational means may promote a deeper understanding of the cultural heritage of the Veneto cities and at the same time a more meaningful learning thanks to its original characteristics.

4 The pilot project: Verona Romana Mobile Learning

4.1 Premises and phases of the project

Verona is a settlement existing since Neolithic times, but the foundation of the city in the current shape and position was made by the Romans in the first century BC. Since then the city has evolved to the present day without interruption the whole city of Verona is part of the UNESCO-protected World Heritage on the basis of the following reasons:

- Criterion (II): For its urban structure and its architecture, Verona is an outstanding example of a city that has developed progressively and uninterruptedly over two thousand years, incorporating artistic elements of the highest quality of different periods that have followed;
- Criterion (IV): Verona represents in an exceptional way the concept of the fortified town in the most characteristic stages of European history.

In the latter half of 2015 we have come up with an experience which targets the primary schools of Verona, the "Quartiere Attivo" association and the University of Padua. Seven 5th year primary school classes, including 140 children, have started from March to participate in the Verona Romana Mobile Learning project which will enable them to learn more about Verona and its classical monuments at the time of the Romans, monuments which are still an integral part of the city's landscape. The experience is closely linked to the

school curriculum because it will engage on the fifth class program, which includes the study of Roman civilization in its phases of the kingdom, republic and empire. The schedule involves the following steps:

1. Agreement with teachers and shared planning of the preliminary lesson and of the tour.
2. Classroom lesson: in this phase, which takes two hours and is held by the historian of Quartiere Attivo, we will provide students with the interpretative tools that will be used during the tour and we will bring the different classes at the same level of knowledge on fundamental aspects of Roman civilisation, especially as regards the construction of cities and infrastructure and to the Verona's context in its main phases.
3. Verona tour: it is the heart of the experience. Led by the historian and by the class teachers aims to discover the Roman remains in Verona in order to understand their function and meaning. It is especially important for this interpretive process also observation of the landscape. Half of the classes use, to support the explanations of the historian, the mixed reality tool (one per student) and the other a paper aid with content as far as possible equivalent (one per student). In both cases the historian, during the tour, in the explanations will refer to the material provided to children. This phase is videotaped so you can conduct video-search and collect quantitative and qualitative data.
4. The fourth phase includes interviews with pupils and teachers, the production of drawings and narrative texts on the experience in order to better understand the learning process mediated by mixed-reality tool and its effectiveness over traditional instruments.

The classes participating in this research are coupled according to a quasi-experimental approach. The couple is part of the same school complex and has the design of the curricular program in common (parallel classes). This is to reduce the incidence of external variables. A pilot experience in which two of the classes involved have gone through all phases of the course has completed to date. Conclusions will be based on the first observation and qualitative data emerging from this experience.

4.2 The prototype of the AR-CIMUVE App: Verona Romana Mobile Learning

The App is designed to be used by students independently, but it can also be complementary to a guided tour or an educational tour led by the teacher. The information that is provided on the screen are complementary and not substitutive to explanations and arguments of the guide. These are presented with the peculiar mode of augmented reality, then superimposed on the real

vision of the artefact, therefore it can be better understood because accurately integrated to the context of the current visual. In the current situation of research and verification, for the creation of the interface, external instruments and services were used. Once integrated, they have enabled the creation of a web-app prototype. While not reflecting in every detail the original idea, it allowed us to test the methodology, the technology and the main features that we re-proposed in the preceding paragraphs. Main development tools were: Holobuilder, Sketchup, Unity 3D and Google Forms. Briefly, Holobuilder, software developed by a start-up based in Aachen, has allowed the integration of equirectangular 360°x180° images (photosphere) with three-dimensional models and sensitive points: the interface features are possible thanks to the engine of this software. Holobuilder team has been active in supporting and implementing some required functions. Sketchup is a program, free for the basic version, which allows to easily create three-dimensional models. Unity 3D is a popular game engine, free in non-commercial version, which allowed the creation of a 3D environment of Verona in Roman times and to extrapolate photospheres. Google Forms allows integration in interface windows and was used to receive feedback, show questions, insights and other images. Looking forward to the diffusion of technologies similar to Google Project Tango, which will allow a precise matching of the virtual level to the real background, it was decided to use an indirect augmented reality: the image on which the virtual layer is superimposed is therefore already acquired and is taken from the memory of the device rather than real-time from the camera. The interface overturns the usual methods of accessing content that includes the departure from a structured text menu that refers to isolated interactive and multimedia content. In the Roman Verona Mobile Learning prototype one begin from an immersive interface. Links to additional content and insights are distributed in the application's mixed reality space, thus making them very contextualized: their position in the virtual space is already an interpretive key of the content. Capabilities include:

- Augmented Reality with superposition of three-dimensional models and other bi-dimensional interactive objects (Fig. 1).
- Virtual Reality, compatible with Google Cardboard (very cheap headset for virtual reality) (Fig. 2).
- Zoomable map (Fig. 1).
- Embed of external content via html5 popup.
- Programmable feedback through Google Forms

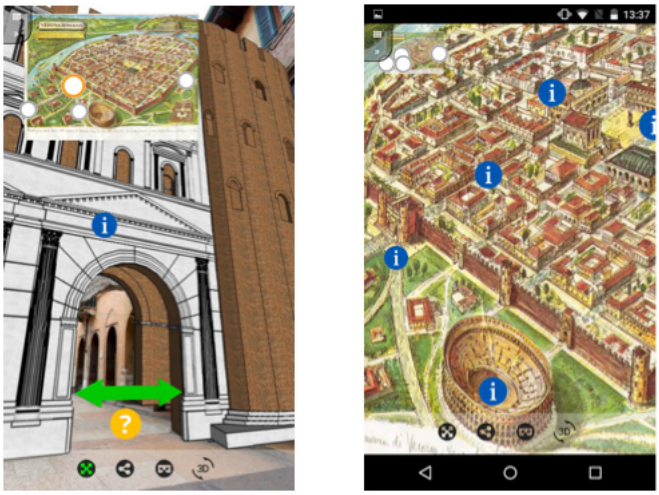

Fig. 1 - Two screenshots of AR – CIMUVE: Verona Romana Mobile Learning's main interface (portrait orientation).

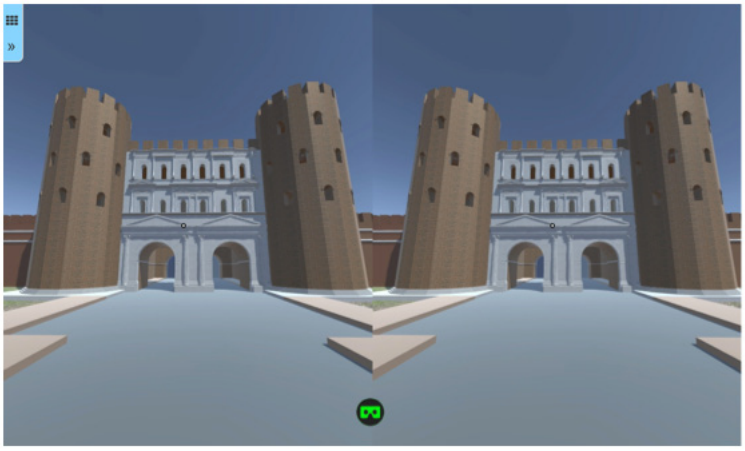

Fig. 2 - Interface of AR – CIMUVE: Verona Romana Mobile Learning in Google Cardboard mode: Porta Borsari virtual reality (landscape orientation).

5 Early feedback and observational data

Some interesting aspects are emerging from observational data on the first couple of classes that has completed the experimental teaching. We detected two critical issues in the use of devices:

- Children do not know how to use smartphones and tablets: contrary to

what is commonly said, the majority of children do not have a good expertise in the use of the Android device. They ignore many of the interactions and basic functions of the operating system.
- As expected, the kids expect immediate feedback from the application. Where this is delayed, immediately they think to a malfunction.

Comparing the approach of the two classes to the visit, from a behavioral point of view, we found that:
- The class that used the device, usually considered by teachers the rowdiest of the two, has maintained a higher concentration during the explanations.
- During the explanation, while in the class that was using the devices pupils were regularly referring to the contents of the application, those of the class with the booklets tended to ignore them unless they be urged by the historian.

The opinions on the tour of the pupils who have used mixed reality technologies show that:
- Most of the pupils in the class who used the devices was not stricken by the use of technology, but from discoveries and information regarding the history of the monuments and landscape.
- The vast majority of pupils in the class who used the devices appreciated the way the App presents contents and calls for broader use of these technologies.
- The technology that has stricken more pupils has been the most immersive one (using Google Cardboard) because it allowed them to see the places as they once were or to see places that you could not access.

Teachers of the classes highlighted that:
- They have not understood from the beginning the potential and implications of these technologies. Now they are convinced of their effectiveness. Also they point out how fundamental is technical expertise for the development of similar projects.
- The project is very positively assessed because strongly integrated into the curriculum and shared with teachers.

Conclusion

With the AR-CIMUVE project we want to experience the role of augmented reality in situated learning processes, especially in informal and non-formal contexts, precisely because we believe that in the near future these will become

more and more important to students and people. Yet, one must consider a setback which could limit its use and effectiveness: real learning contexts are still limited and the usage of AR tools is tied with sporadic non-formal activities; still, much of the teaching takes place in traditional classroom settings (Auld & Johnson, 2015). In order that AR may become an effective mediator in the learning process, one must reform school curriculum and learning settings so that informal experiences made by students outside school using their mobile devices, also with AR software applications, can be included.

These experiences, with the help of the teacher, could become stimulus for discussions in class so that students do not regard learning experiences in informal learning spaces as being different from those at school. In this sense teaching methods which are oriented towards the Project Based Learning in a "flipped classroom" approach could favour this process, thus bridging the gap between formal and informal learning. The pilot project that is taking place in Verona is designed to encourage and spread this kind of teaching practices. Thanks to the results and feedback that we will receive at the end of this experiment we will be able to fix and to further develop the application. Also we are going to verify the effectiveness of both teaching and education, in the perspective of putting in place an adequate methodological model.

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