Virtual Reality and Museum

An Educational Application for Museum Education

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***Abstract*—This paper discusses the development of a virtual reality museum. An effort was made so that the virtual museum represents the Byzantine, medieval museum in Rhodes as closely as possible. Simple and low cost tools were used to allow rapid development of relatively good quality applications. This was attempted to validate our belief that the construction of VR applications is within the abilities of the majority of computer users. In this case and taking into account the well documented educational value of VR, it would be possible to assert that teachers could construct and use VR applications in their everyday teaching.**

***Index Terms*—Museum Education, Museums, Virtual Reality**

I. MUSEUMS AND EDUCATION

Museums are places that include collections of varied content. Despite differences, these collections have usually three common characteristics: i) they consist of samples of human and natural history, ii) they contain objects emanating from the past and iii) they were assembled with some degree of expediency from some holder or commissary of the museum, who believed that the total was in some way more important than the sum of its parts [1].

Museums aim at communication. In most cases, the intention for such communication has pedagogic purposes and is viewed as an educational mission for the social milieu [2]. Museums are unique places that enrich and support the learning process of individuals of all ages. According to the International Council of Museums (ICOM), museums are usually nonprofit organizations in the service of society, promoting its development. The museum acquires, maintains, communicates and exhibits the material testimonies of humans and their environment, aiming at study, education and entertainment [3].

From the above definition, it becomes apparent that one of the most important aspects of the museum's social role is education, rendering them unique places that can enrich and support the learning process. In fact, this can be achieved either through the educational system itself (e.g. through educational excursions), or through educational programs that emanate from the communication and collaboration between the school and the cultural institution. There are also cases where the collaboration takes place between museums and other institutions such as hospitals, prisons and various groups of society. Museums can serve learning regardless of age. In this sense, museums are institutions that contribute to lifelong learning.

Museum Education studies the pedagogic and museological principles that condition the cultural and educational policy of museums and generally determines the frame for planning, implementation and evaluation of educational programs. The cognitive theories that provide the theoretical basis of Museum Education are constructivism, the theory of multiple intelligences and the holistic model of communication, common characteristic of which is the emphasis on the individual characteristics of visitors/learners [3].

What is important to stress out is that usually museums function as places of informal education, a very important educational process in the present era. The attendance to this process, in most cases, is voluntary and spontaneous [4]. In a museum's environment, learning takes place within three frames: i) the personal context which refers to the degree of intrinsic and/or extrinsic motivation shown by learners, since motivation greatly affects the learning outcomes, ii) the physical context which describes the sets of cues that help learners make sense of phenomena, artefacts and events, that are often more difficult to appreciate in formal education and finally iii) the socio-cultural context which is maybe the most important, yet it has not been well researched. Socio-cultural context deals with the interactions between learners/visitors and the place of learning/museum [5].

II. MUSEUMS, ICT AND VIRTUAL REALITY

Educational curricula acknowledge the value of museums -specifically on issues of history and culture- and include visits in relevant places. However, the traditional didactic practices applied in this context do not always achieve the expected results [2], hence the need for a different approach regarding Museum Education. The main point in this paper is that ICT can contribute successfully in the evolution of museums and in the promotion of their role in the learning process.

ICT has wide applications in museums. One of the early applications was the management and documentation of collections. However, a more recent and highly important contribution of ICT concerns the creation of digital museums. With digital museums, the main advantage is not simply the digitalization and electronic promotion of the museums' material. The important element is that this digitalization induces a fundamental change: museums from occasional and static means of authority become means of daily, dynamic, direct and personal instruction [6].

The term that is often used when the digitized exhibits of a museum are publically available, is "virtual museum" According to Lewis, "virtual museums" are considered the collections of digital pictures, sound, text and various data of scientific or cultural interest, which are accessible via electronic means [7]. In addition, according to Bearman, the difference between the exhibits that are in display and exhibits in storage is decreased -if not eliminated- since the entire the collection can be accessible [8].

There is an increasing number of museums that present part or all of their exhibits digitally and offer virtual tours. The simplest form is a multimedia application or static web pages using text, photographs, video and audio. In more advanced applications high quality photorealistic reconstructions of the museums are used combining 360^o panoramas and an interface that allows the user to navigate through them. As such, one can mention the the Museum of Science History in Florence, in which QuickTime VR is used for the virtual tour [9], the Museum of Louvre that also uses QuickTime VR [10], the Oxford Museum [11] and the Museum of History in the University of Athens that uses Java in its web pages [12].

However, as attractive as these applications might be, they are not without disadvantages. The general idea of a 360^o panorama is that one stitches together photographs so that they cover a complete circle. In simple applications the user can just rotate around a central axis. In more advanced ones, it is possible for the user to move forward and backwards and click on objects in order to get the relevant information (in the form of text, video or audio file). The usage of photographs allows an accurate and realistic illustration of the museum, however when the user moves very close to the boundaries of the area, the images become blurred. Furthermore, the user cannot observe an object from any desirable angle other than the one of the initial photograph. Manipulation of objects is not possible. Consequently, one can claim that there is no true interaction and free exploration of the museum's area.

Solution to the above problems comes from another type of ICT applications, namely Virtual Reality (VR). The high degree of interaction is a unique characteristic of VR applications. This means that within a virtual environment free navigation and exploration is permitted. The user can observe elements of the virtual world from any desirable angle and can interact with its objects, as long as the application's developer has made provisions for that. VR offers experiences through the "actual" use of the virtual objects. Interaction is mandatory; the user/learner actively participates and is given the ability to control the learning process [13].

Other unique characteristics of VR are:

- Perspective. In VR applications it is possible to choose (and to switch between) the perspective, the way with which the user sees the virtual environment. Usually in VR applications, the "first person"[1] view is used instead of "third person"[2] view, which is used in most multimedia applications. With first person view the user has a more direct contact with the environment, which leads to immersion.
- Immersion. The term describes a mental state in which, due to controlled sensory input, the user feels present/immersed in the virtual environment. Technically speaking, immersion depends on the realism of the virtual world, how accurately a real or an imaginary environment is illustrated and how it is related to the application's 3D graphics quality [14].

Specifically, in case of virtual museums, VR has certain important advantages which are the following [15]:

- Realistic simulation of the environment (e.g. museum's rooms) and exhibits.
- Suppression of time and distance for accessing the corresponding material.
- Interaction with the exhibits.

In other words, a virtual museum is an imaginary/immaterial area -a reconstruction/simulation of a real or unreal museum- where visitors can navigate freely, without the necessity of actually being in the real museum, although it gives the impression of "being there". This can be a great advantage for residents of disadvantaged areas (e.g. remote and/or rural) who do not have the opportunity to visit such places. Pedagogically speaking, students who "visit" virtual museums can come in direct contact with the exhibits, can select, focus and manipulate exhibits of their interest. Eventually, such environments can provide students with activities that have educational content, prompting them to interact with the exhibits, to discover, to wonder and finally to learn.

In the past few years, an increasing number of museums use VR applications in order to present their content. Indicatively, one can mention the virtual museum of Kon-Tiki [16], the project "Virtual Museum Net of Magna Graecia" [17], Ulysses's Museum [18], the Ancient Militos [19] and finally the Temple of Zeus in Ancient Olympia [19]. The virtual museum of Kon-Tiki contains exhibits from various sea goods and boats. The project "Virtual Museum Net of Magna Graecia" refers in the archaeological region of Calabria in Southern Italy and offers a virtual tour of this area. Ulysses's Museum was developed as a tool for teaching mythology in primary school and it does not represent an actual museum. Instead, it contains exhibits from various museums and libraries such as the National Archaeological Museum of Athens, the British Museum of London and the Metropolitan Museum of New York. Finally, the projects Ancient Militos and the Temple of Zeus in Ancient Olympia, which were developed by the Foundation of the Hellenic World, are not museums rather than simulations of how the original places looked like in antiquity.

III. THE PROJECT'S RATIONALE

Having as stimulus the above examples of virtual museums, we considered an interesting scientific and technological challenge the development of a similar application. For this purpose, we selected the exhibition of the early-Christian period, Byzantine and medieval discoveries of Rhodes, Greece. The exhibition resides in the Old City of Rhodes, in the southwestern wing of the ground floor of the Palace of Grand Master. The $452m^2$ of the exhibition are divided into seven rooms, in accordance to seven thematic units: Introduction, Economy, Social life, Defence and Administration, Intellectual life, Religion and Art. For our application we chose three of these rooms, specifically: room five (Intellectual life), six (Religion) and seven (Art).

[1] In first person perspective, the user can only see his hands and parts of his body, as we do in the real word.

[2] In third person perspective, the user controls and sees an "avatar", a representation of the user.

Room five contains exhibits such as manuscripts and printed books, relevant with the history of the knightly battalion. It also contains copies of texts, letters and contracts about Rhodes, Byzantine icons, marbles and two sepulchral columns. Room six contains Byzantine icons (most of them painted in both sides) and two show-cases with ceramic, metal, and marble exhibits, such as small vessels, crosses, oil lamps, etc. Finally, in room seven there is a reconstruction of a Byzantine temple, murals, mosaics and a small showcase with objects that where used in the construction of buildings.

The development of the application as well as its experimental implementation was designed to be applied to the Rural Wings Project. The main objective of the project is to offer e-learning services to a variety of users being at school, at work or at home, by installing DVB/RCS satellite terminals equipment into 126 pilot sites in 13 European Countries (Greece, Spain, Sweden, France, Romania, Cyprus, Estonia, Poland, UK, Israel, Armenia, Georgia, and Switzerland). These pilot sites refer mainly to isolated and remote villages in rural areas and geographical locations such as mountainous sectors or islands where fast internet access (i.e. ADSL) has never been possible before. Rural Wings' aspiration is not only to provide e-learning services to isolated areas, but also to cover people's needs and to offer new perspectives for their life in all its aspects [20].

From the above, it becomes clear that the philosophy of Rural Wings as well as the uses of virtual museums share a common ground. They both seek for the narrowing of the cultural, educational and professional gap between the privileged and the unprivileged residential areas, between the ones that have access to cultural/educational goods and services and the ones that do not.

What distinguishes the present effort from the existing VR museums is a number of prerequisites that we have set. First of all, and quite understandably, we wanted to construct an application that will represent with adequate precision an existing museum. This means that:

- The virtual rooms had to correspond to the real ones regarding their architectural setup (e.g. ground plan, decorative elements, structural materials, etc).
- The virtual exhibits also had to correspond to the real ones.
- The whole "atmosphere" (e.g. lightning, showcases and explanatory texts) of the virtual rooms had to resemble the one of the real rooms.

On the other hand, and in contrast to a typical VR application, we wanted:

- The project to have an exceptionally small cost, if possible no cost at all. The software for the development of VR applications has a cost that varies from few hundreds up to several thousands of euros. The same applies for software for the construction, manipulation and editing of 3D models and for the software used for photo editing. We decided to search for and use VR developing software, 3D models editing programs and image editing programs that are open source or free of charge or at least have an exceptionally low cost (under 50 Euros each).
- Short development time and a small number of individuals involved. VR applications, simulations and, in general, applications that use 3D models, require many months for their development and employ teams of experts (e.g. programmers, modellers, photo editing experts). It is belief of the authors that it would be feasible to complete the work in much less time after the first hands on experience.
- The final application to be able to run smoothly in middle range computers. It is known that 3D applications are extremely demanding when it comes to graphic processing power. It is also known that, among users, only gamers equip their systems with very well up to high-end graphics cards. Contrary to these, we decided to test if it is possible, and under which circumstances, a VR application will be able to run smoothly in middle range computers equipped with average or even low-end graphics cards.

The main rationale behind these objectives was the need to validate our belief that the construction of VR applications -up to a certain complexity- is within the grasp/abilities of the vast majority of computer users. If such a notion is valid and taking into account the well documented educational value of VR, one would be in position to proclaim that educators can and should construct and use VR applications, freeing themselves of the dependency and the cost of ready-to-use applications. The above can also apply to anyone interested in developing any type VR application.

As far as education is concerned, it is our belief that one of the drawbacks regarding the educational uses of ICT is that, even though "general purpose" commercial software is widely available, there is lack of tailored made applications. This holds even more in the case of VR, where the total number of applications is very small. Commercially available software partially addresses the needs of a wide range of different types of users, failing to address wholly the needs of a specific group. On the other hand, customised software -capable to address the needs of a specific classroom, group of students or even a single student- can only be made if the teacher of these students is directly involved during its development. However, teachers assign to themselves the role of the user rather than the role of the developer, considering such an obligation to be out of their immediate interests or abilities. The task of convincing them that they can develop VR applications -which are more complicated than other types of applications (e.g. multimedia and hypermedia)- is hard. The first and most important step is to find easy to use tools.

For the above reasons, we chose Reality Factory [21] an open source program that its main purpose is the development of 3D "shoot them up" games. This is justified on the grounds that 3D games and VR applications have many similarities [14]. Further more, the above mentioned program, offers a windowed environment for the development of applications and does not require any programming skills. Gimp, which is also an open source software was used for photo editing [22]. For the construction and editing 3D models, we chose MilkShape 3D, a popular, low cost software [23].

IV. CONSTRUCTING THE APPLICATION

The construction of a Virtual Reality application, from the simplest one up to the most complex, is a multi-functional task that includes two distinguishable stages: i) collection and editing of the necessary material and ii) construction of the virtual world.

The first stage includes: i) collection and editing of the photographic material and in the case of the virtual museum, editing of explanatory texts for the exhibits, ii) construction of the texture libraries and iii) the development and editing of the 3D models. In the three museum's rooms there are more than 150 objects; therefore an equal number of 3D objects had to be constructed.

The second stage includes: i) the development of the virtual rooms, ii) the placement of 3D models and iii) the addition of special elements and interactions.

A. Collection and editing of the photographic material, editing of explanatory texts for the exhibits

In this stage, the most laborious and the second most time consuming regarding the tasks to be completed, an extended number (more than 900) of photographs was taken, which included aspects of the rooms and the exhibits taken from multiple angles. The museum authorities granted permission and a member of the team visited the museum five times. No special equipment was used, except of a 7.2 Mpixels semi-professional camera. From this multitude of photographs around 200 were selected. Using the photo editing program areas of the photographs were selected suitable for becoming the textures of the 3D models and the virtual rooms (walls, floors, etc). These areas were copied and pasted as new files. The new files were once again edited, changing their brightness, contrast, perspective, file type (bitmap format was required) and dimensions (dimensions in pixels were required to be a number that corresponded to a power of 2) (image 1). At this stage, image files of the texts were created that will later became the explanatory texts of the exhibits (image 2).

B. Construction and editing of the 3D models

The greatest challenge and the most time consuming process during the development of the application was the creation of the 3D models of the various exhibits. The process was challenging since no member of the team had the required expertise. A significant amount of time was spent in learning the program and afterwards in finding and applying techniques for the construction of the necessary 3D models. The number of polygons of each model was drastically reduced in order to make the final application more lightweight (images 3c, 3d) and the appropriate textures were applied (image 3e). Finally, the models were edited with a tool included in the program for the creation of the virtual world and were converted to the suitable file format.

C. Construction of the texture libraries

As already mentioned, a number of image files were to become textures of the virtual rooms. Using a tool included in the program for the creation of the virtual world, these images were added to existing or new texture libraries, making them directly available to the program without further editing.

Figure 1. Example of an original and edited photo

Figure 2. Example of an explanatory text

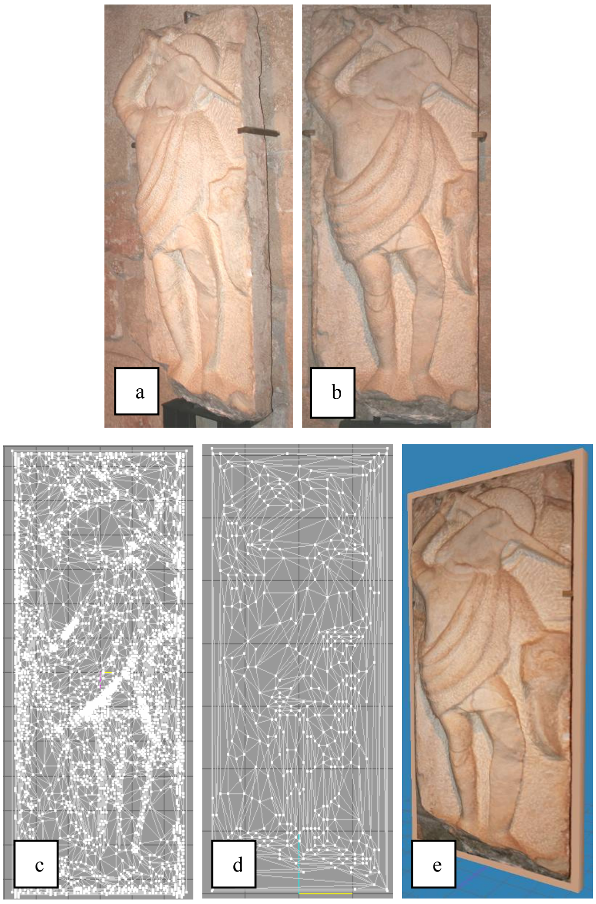

Figure 3. Construction stages of a 3D model (a & b original, c & d polygon reduction, e final 3D model)

D. Development and editing of the virtual rooms

First, the ground plans of the selected rooms were designed. Following these plans, three virtual rooms were constructed, adding floors, ceilings, walls, doors, stairs, and arches. At great deal of time was devoted in learning the functions of the software rather than the actual construction of the rooms.

E. Placement of the 3D models

In this stage, the virtual world was populated by adding the 3D models that represent the exhibits of the museum (image 4). Soon it was realised that the rooms were "crowded" with 3D models/exhibits and the potential user would not have a clear view and "feeling" of each one of them. Therefore, it was decided to add 2-4 "extra" rooms (2 in room 5 and 4 in rooms 6 and 7). In these extra rooms, we split the exhibits, increasing the scale of the 3D models and placing them at a distance from each other. By doing so, the user would be able to have a clearer and multi-angle view of the exhibits. Finally, for the aesthetic improvement of the application, lights and a looping music were installed.

F. Addition of special elements-Interactions

This was the last stage of the application's development. The main rooms were not connected with their extra ones. This was done in order to decrease the load of the computers running the application. In order to connect them, elements were added that allowed "teleportation" from one room to the other. Each room along with its "extra" rooms constituted one file, again in order to reduce the computational load. Once more, elements were added that allow the loading of files and the smooth transition from one main room to the other. Finally, the appearance of the explanatory texts when a user "touched" a model/exhibit was regulated by another set of the program's elements. The end result was a virtual museum that closely resembled the real one (image 5).

G. Testing the application

All the previously described tasks were carried out using middle range computers. Given that the application's was going to be administered to primary school students using a typical school computer lab, our main concern was the application's performance. This is because primary schools in Greece are equipped with computers that are four to five years old on average. Extensive tests revealed that the application runs satisfactorily in computers with relatively low specifications without compromising its quality. For instance, computers equipped with graphics cards at least three generations old (namely Nvidia's 5XXX and 6XXX series) managed to produce 50-100 frames per second (fps) depending on the number of models present in the scene.

It is important to mention that the application's development team consisted of three persons but all the previously described stages were handled by only one. This person, although a good user of typical computer applications (e.g. office suits and photo editing programs), had no experience in any type of the software used. Although this was one of the prerequisites that we had set, it also led in the significant increase of the time spent for the development of the application, because the usage of these programs had to be learnt. Also many hours were spent for learning and perfecting techniques for the rapid development of 3D models. Needless to say that since we documented the whole process in a form of a step-by-step guide, in the future, the amount of time dedicated for the development of similar applications is going to be significantly decreased. The total hours devoted for each stage are shown in table 1.

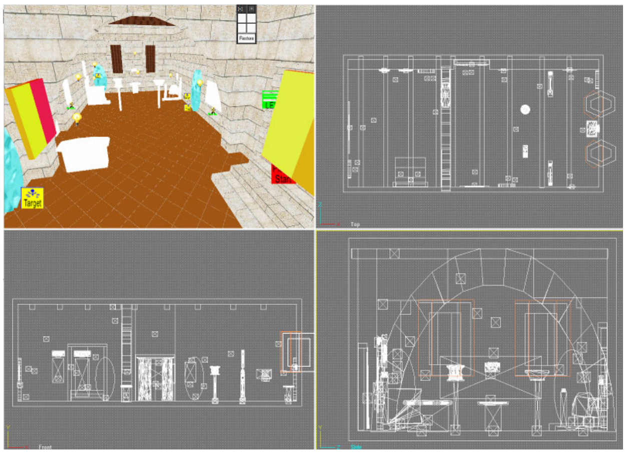

Figure 4. Snapshot from the construction of the virtual rooms

Figure 5. Comparison between the real and the virtual museum

TABLE I.
HOURS SPENT FOR THE DEVELOPMENT OF THE APPLICATION

Task	Learning the program(s) hours	Working hours
Collection and editing of the photographic material, editing of explanatory texts	0	50
Construction of the texture libraries	>1	5
Construction and editing of the 3D models	40	200
Development and editing of the virtual rooms	40	30
Placement of the 3D models	0	30
Addition of special elements-Interactions	0	30
Total	**81**	**345**

V. PILOT IMPLEMENTATION

As mentioned in the previous chapter, the application is to be used by primary school students. Consequently, there was a number of elements that needed clarification regarding the use of a VR application by young students (e.g their reactions, the cognitive outcomes, possible difficulties during the usage of the application). In order to gather data, make observations and eventually come to some conclusions, a short pilot implementation was set up. Forty students of a primary school were chosen (20 of the fifth and 20 of the sixth grade). Each class was divided into two groups (5A, 5B, 6A, 6B). All students in both classes were already familiar with contemporary teaching methods (e.g. cooperative learning and working in groups). During the first day and for one didactic hour, the students of group 5A and afterwards the ones of group 6A, used the application and specifically room 6 of the virtual museum. Each student had his/her own computer at his/her disposal. At the same time, room 6 was presented to students of group 5B and afterwards to students of group 6B, using a PowerPoint presentation, video projector and printed material.

During the second didactic hour, all students of the fifth grade returned to their classroom and were occupied in creative activities. These activities included writing a couple of paragraphs regarding their comments and impressions of what they just had seen, drawing, making their own reconstructions of the exhibits using clay and free conversation regarding the whole experience. The same applied to students of the sixth grade.

The second day the whole scheme was repeated. However, this time we chose room 7 and groups 5B and 6B used the application, while groups 5A and 6A were taught using conventional teaching methods (PowerPoint presentation, video projector and printed material). Once again, there were similar activities during the second didactic hour.

For gathering of experimental data, six different questionnaires were administered. One was completed by the groups' teachers and included questions referring on the skills and learning characteristics of their students. The other five were completed by the students. One had questions about the students' acquaintance with computers and game consoles and was administered the day prior to the pilot implementation. The other four (2 for room 6 and 2 for room 7) were given during the second didactic hour of each lesson and aimed in determining if knowledge was acquired and to what extent, but taking care not to be taken as tests. Observations made during the lessons were also recorded. Finally, the students' written comments, their drawings and their clay "exhibits" were used for evaluation purposes.

Analysis of the data which followed, focused in five categories on the: i) degree of interest, ii) degree of amusement, iii) achievement of educational goals, iv) impact in collaboration between students and v) effects in students' creativity.

As for the first category, all students -in both types of lessons- initially had an increased degree of interest. However, in traditional teaching, there was a sharp decline in the degree of interest during the teaching hour, meaning that students were getting increasingly bored. This was not the case in the lessons where the VR application was used.

Data regarding the degree of amusement showed that only 30% of boys and girls want to see the rest of the museum through a PowerPoint presentation, compared to a nearly 100% that want to “visit” the rest of the museum with the use of the VR application.

The achievement of educational goals, was the most important and most representative regarding the fulfillment of our goals. Data showed that the majority of students who participated in teaching with VR application had better learning results compared with those that attended traditional learning processes. Some of the results are shown in table 2.

TABLE II.
PERCENTAGE OF CORRECT ANSWERS IN FOUR INDICATIVE QUESTIONS

		Room 6		Room 7	
		5th Grade		6th Grade	
		Quest. a	Quest. b	Quest. c	Questi. d
PowerPoint presentation	boys	0%	43%	6%	40%
	girls	10%	33%	40%	60%
VR application	boys	57%	86%	60%	100%
	girls	100%	100%	100%	100%

For the impact in collaboration, it was observed that all students actively participated and collaborated well in the activities that followed both teaching methods. However, one has to stress out that designs and constructions of students that attended the VR sessions were more detailed and better represented the real exhibits, in contrast to the ones that were made by the same students when they attended the traditional lessons. The above is an indication that their creativity was somehow positively affected by the VR application.

We have to mention that the students' attitude was very positive from the beginning of the pilot implementation. Their attitude towards the application did not change even after the completion of the lessons, while it was interesting to observe that they wanted to continue the lessons and give them the opportunity to "visit" the other rooms of the virtual museum. Finally, teachers' collaboration was also very enthusiastic and made the entire effort much easier helping and guiding the students.

VI. CONCLUSIONS

The project presented in this paper had two main objectives. The first was the need to investigate whether the development of VR applications is as complex as the vast majority thinks or if "clever" workarounds do exist, making such a task more appealing to developers and users. The second derives from the fact that Museum education is a relatively new branch of the educational sector. VR applications aiming at Museum Education are scarce which means that there is a fertile ground for experimentation and further development.

As for the first objective, we selected an existing museum of which acquaintance with its exhibits would provide a useful experience to students and to visitors. Its digitalization was performed using programs that did not need experts for their handling, nor extended amount of time for the development of any virtual environment. Innovative techniques were used that allowed, to a point, the rapid development of complex 3D models. The overall time devoted for the development of the application did not exceed two months and involved just one person. This time can be further reduced once familiarization with the relevant software is achieved. The total cost was kept well under the 100 Euros threshold. No advanced computers are needed for running the application. Finally, the functional and aesthetic outcome of our effort affirmed our aspirations.

As for the second objective, the results of our pilot implementation confirmed that VR in museums can successfully serve educational goals. The students that participated in this VR learning project "embraced" with great enthusiasm the virtual museum, were highly interested in the subject during our presentation and were willing to take part in the activities that followed.

Their answers regarding the acquisition of knowledge showed that the majority of the participants in the VR sessions had better learning results, could describe and design the exhibits better than the students that attended the conventional lessons.

In conclusion, the team believes that the construction of VR applications is a highly promising, low-cost possibility. It has but one main prerequisite: it needs a certain time for familiarisation with the software used.

It should be noted that this project is a work in progress and our goal is to further investigate how of primary school students interact with it. However, as mentioned above, the experimental data that were obtained reinforce our belief that VR learning environments have positive effects in the educational progress.

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