

Educational Uses of Virtual Reality: Constructing a VR Museum

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Key words: *Virtual Reality, museums, museum education*

Abstract:

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

1 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 in individuals of all ages. According to International Council of Museums (ICOM), museums are usually nonprofit organizations in service of society, promoting 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 [3], rendering them unique places that can enrich and support the learning process. In fact, this can be achieved either through the educational system itself (i.e. through educational excursions), or through educational programs that emanate from the 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 societies. Museums can serve learning regardless of age. In this sense museums are institutions that can contribute to lifelong learning.

Museum Education studies the pedagogic and musicological principles and terms 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 intelligence and the

holistic model of communication, common characteristic of which is the emphasis in the individual characteristics of visitors/learners [3].

What is important to stress out is that usually museums function as places of informal education, an educational process that is considered very important. The attendance in this process, most of the times, is voluntary and spontaneous [4]. In places as the museums 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. 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 sociocultural context which is maybe the most important, yet it has not been well researched. Sociocultural context deals with the interactions between learners/visitors and the place of learning/museum [5].

2 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 practice applied in this context does not achieve the expected results. The main hypothesis in this work 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 first applications was the management of collections and the documentation. However, a more recent and highly important contribution of ICT concerns the creation of digital museums. With digital museums, the main achievement 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 publicly 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° 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° panorama is that one can stitch together photographs so that they cover a complete circle. The usage of photographs allows a high degree of realism, but that is the only advantage of this method. 360° panoramas limit the user in many ways; he/she can only rotate his/her viewpoint, move forward and backwards and click on objects in order to get the relevant text, video or audio file. Consequently, there is no true interaction and no exploration of the area that represents the museum.

Solution on 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:

The interface. The term is used for describing the means of bidirectional communication between the user and the computer, i.e. the keyboard, the mouse, the monitor, etc. The more "natural" this communication is, the less the interface is observable by the user. VR uses devices that replace the mouse and the keyboard. By doing this, the interface is almost eliminated.

Perspective. Another characteristic of VR is the possibility of altering of perspective, the way with which the user sees virtual environment. In VR, the "first person"¹ view is used instead of "third person"² who is used in most multimedia applications. With first person view, the user has a more direct contact with the environment, which leads to immersion, another characteristic of VR.

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 two factors. The first one is the realism of the virtual world, how accurately a real or an imaginary environment is illustrated and is related to the application's 3D graphics quality [14].

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

A realistic simulation of the environment (i.e. 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 (i.e. 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

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

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

Olympia, which were developed by the Foundation of the Hellenic World, are not museums rather than simulations of how the original places should look like in antiquity.

3 The application's rationale

Having as a stimulus the examples of virtual museums that were presented in the previous chapter, we considered an interesting scientific and technological challenge the development of a similar application in a museum in Rhodes, Greece. For this purpose, the content we selected was the exhibition of the early-Christian period, Byzantine and medieval discoveries of Rhodes. The exhibition resides in the Old City of Rhodes, in the south-western wing of the ground floor of the Palace of Grand Master. The 452m² 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 and specifically rooms five (Intellectual life), six (Religion) and seven (Art).

Room five contains exhibits such as manuscripts and printed books, relevant with the history of the knightly battalion. It also has 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 showcases 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 were used in the construction of buildings.

The development of the application as well as its experimental implementation was decided to be part of 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:

1. The virtual rooms had to correspond to the real ones regarding their architectural setup (i.e. ground plan, decorative elements, structural materials, etc).
2. The virtual exhibits also had to correspond to the real ones.
3. The whole "atmosphere" (i.e. lightning, showcases, explanatory texts, etc) 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:

1. 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 and free of charge or at least have an exceptionally low cost (under 50 Euros each).

2. 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 (programmers, modellers, photo editing experts, etc). We wondered if it would be feasible to complete the project in less than three months, while involving three individuals (preferably less). Their computers skills would have to be of an average advanced computer user with minimal or none prior computer programming knowledge or other computer expertises (i.e. expertise in constructing 3D models).
3. The final application to be able to run smoothly in middle range computers. We know that 3D applications are extremely demanding when it comes to graphic processing power. We also know that, among users, only gamers equip their systems with very good-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 computers that are equipped with average-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.

Why is it so important for one to be able to develop his/her own applications? As far as education is concerned, we believe 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 is even more true in case of VR where the total number of applications is insignificant. 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 a task 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 (i.e. multimedia, hypermedia)- is hard. The first and more important step is to find easy to use tools.

For the above reasons, we chose 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]. Furthermore, the above mentioned program, offers a windowed environment for the development of applications and does not require any programming skills. Open source software was also used for photo editing. For the construction and editing 3D models, we chose a low cost -and popular- program.

4 Constructing the application

The construction of a Virtual Reality application, from the simplest one up to the most complex, is a multifunctional task that includes two distinguishable stages: i) collection and editing of the necessary material and ii) construction of the virtual world (*figure 1*).

The first stage includes: i) the collection and editing of photographic material and -specifically in the case of the virtual museum- the editing of explanatory texts for the exhibits, ii) the 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 would have 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.

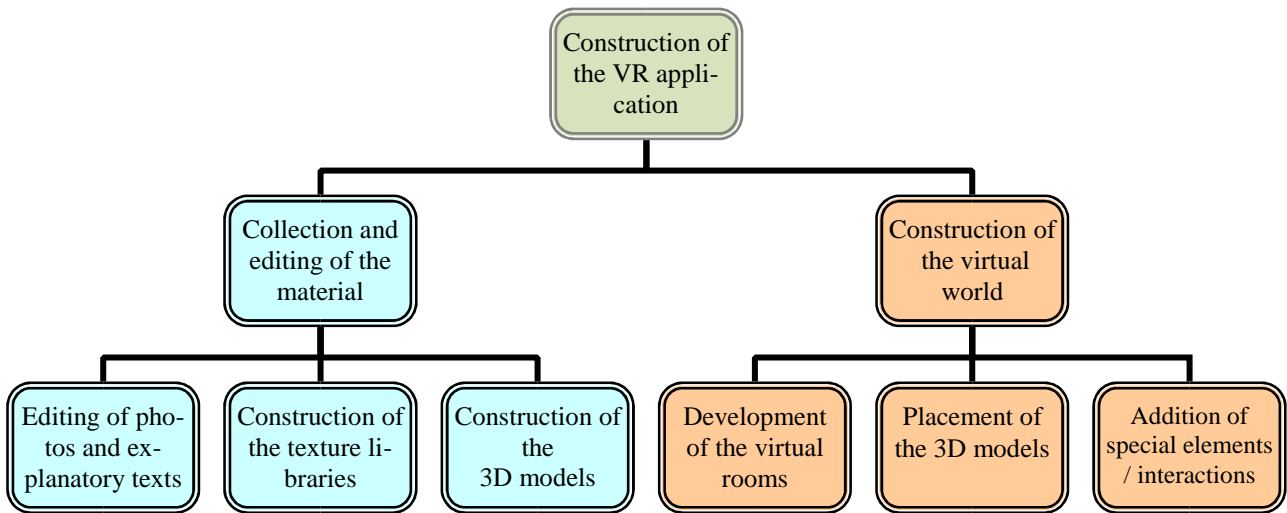


Figure 1: Construction stages of the virtual museum

Collection and editing of the photographic material, editing of explanatory texts for the exhibits: In this stage -which was the most laborious and the second most time consuming regarding the tasks that had 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-.bmp 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, we also created image files of the texts that will later become the explanatory texts of the exhibits (image 2).



Image 1. Example of an original and edited photo

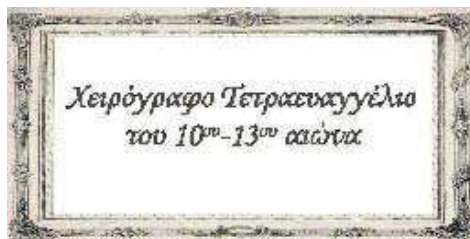


Image 2. Example of an explanatory text

Construction of the texture libraries

As we 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.

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 because no member of the team had the required expertise and because -most importantly- none of the existing techniques for the development of 3D models could be applied in many of the museum's exhibits due to their complexity. Therefore, we had to devise not just one but three completely new techniques that allow the rapid construction of a 3D model by using just one photograph of the original item/exhibit [21]. The number of polygons of each 3D 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 3D 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.

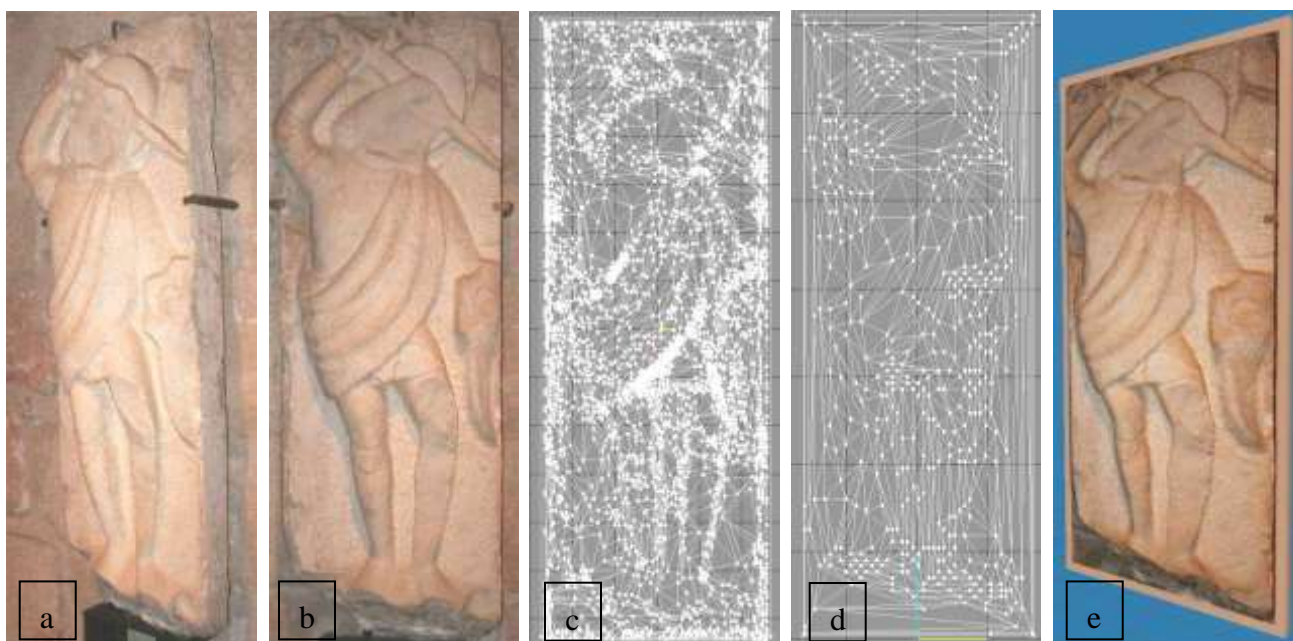


Image 3. Construction stages of a 3D model a & b original, c & d polygon reduction, e final 3D model

Development and editing of the virtual rooms

Firstly, we designed the ground plans of the selected rooms. Following these plans, we constructed the three virtual rooms, adding floors, ceilings, walls, doors, stairs, arches and in general every architectural element that they have. Most of the time in this phase of the work was dedicated in learning the program rather than in the actual construction of the rooms.

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 we 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, we decided to add 2-4 "extra" rooms (2 in room 5 and 4 in rooms 6 and 7). In these extra rooms, we split and added the exhibits of their respective rooms, 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, we placed lights and a looping music.

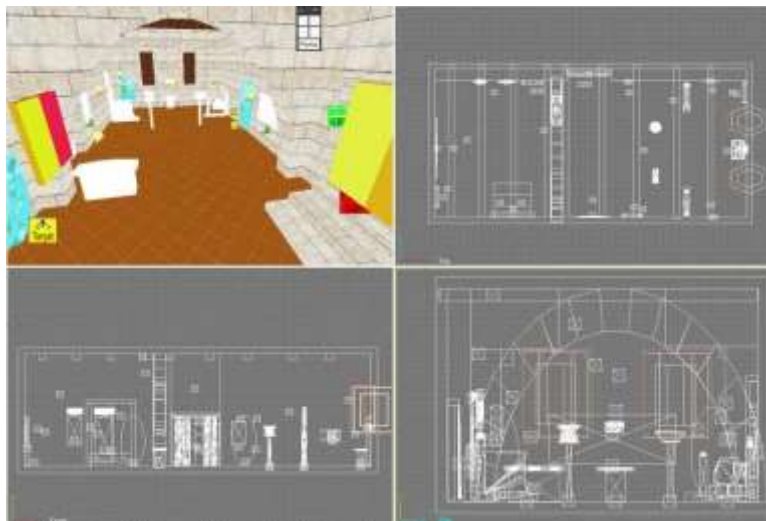


Image 4. Snapshot from the construction of the virtual rooms

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, we added elements that allow the "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 "touches" 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*).



Image 5. Comparison between the real and the virtual museum

Tests regarding the application's performance revealed that it runs very satisfactorily in computers with relatively low specifications without compromising the quality. For instance, computers equipped with graphics cards at least two generations old managed to produce 50-100 fps depending on how many models were present in the scene.

What is important to mention is that the application's development team consisted of three persons but all the previously described stages were handled by a just one. This person, although a very good user of typical computer applications (i.e. office suits and photo editing programs), had no experience whatsoever in any type of the software used in 3D applications. 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. It also has to be noted that even more hours were spent for inventing and perfecting techniques for the rapid development of 3D models. Needless to say, that, in the future, one has to spend only a few hours in learning those techniques. The total hours devoted for each stage were approximately the following:

Task	Learning the program(s)	Invention and perfection of new techniques	Working
Collection and editing of the photographic material, editing of explanatory texts	0	0	50
Construction of the texture libraries	1	0	5
Construction and editing of the 3D models	50	120	60
Development and editing of the virtual rooms	40	0	30
Placement of the 3D models	0	0	30
Addition of special elements-Interactions	0	0	30
Total	91	120	205

5 Pilot implementation, preliminary results

One of the unknown factors during the construction of this application was the reaction that primary school students might have when using it. For this purpose, we organized a short pilot implementation in order to gather data, make observations and eventually come to some conclusions. 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 (i.e. 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 with the use of a PowerPoint presentation (constructed also by us), 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 the 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 and were trying to determine if knowledge was acquired and to what extent, but taking care to be seen as a test. The students' written comments, their drawings and their clay "exhibits" were also used for evaluation purposes.

Analysis of the data which were gathered is still in its preliminary stage, but the trends are quite clear.

The students' attitude was very positive from the beginning of the pilot implementation. Teachers' collaboration was also very enthusiastic and made the entire effort much easier helping and guiding the students. Students actively participated in both types of lessons (conventional and VR) and in the activities that followed. 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.

6 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 not only to students of our country but also to foreigners. Its digitalization was done using programs that neither need experts for their handling, nor time for the

creation of any virtual environment. Innovative techniques were used that allow -up to a certain 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 programs 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 preliminary 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 our virtual museum, were highly interested in the subject during our presentation and were willing to take part in the activities that followed.

Their answers on relevant questions regarding acquisition of knowledge showed that the majority of the students who participated in the experimental teaching with VR application had better learning results compared with those that attended traditional learning processes. Moreover, the designs and constructions of the first group of students were more detailed and represented better the reality, in contrast with the constructions of the second group.

In conclusion, the team believes that the construction of VR applications is a highly promising, lowcost 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 preliminary results that were obtained reinforce our belief that VR learning environments have positive effects in the educational progress.

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Session

Pa-6B: Multimedia and Virtual Reality

Time: Friday, 26/Sep/2008: 11:00am - 1:00pm

Location: Drau 1+2, Holiday Inn

Session Chair: Prof. Linmi Tao

Parallel Sessions Track B

Full Paper Session

Presentations

Pa-6B: 1

Integrating the Sense of Smell in an Educational Human-Computer Interface

Miguel Angel Garcia-Ruiz¹, Samir A. Samir A. El-Seoud², [Arthur Edwards](#)¹, Jihad Mohamad AL-JA'AM³ and Raul Aquino-Santos¹

¹University of Colima, Mexico; ²Princess Sumaya University for Technology (PSUT), Jordan; ³College of Computer Science and Engineering, Qatar

Pa-6B: 2

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Pa-6B: 3

Ariann@ project: E- Learning Platform for University Guidance

Vincenzo Di Lecce¹, [Antonella Giove](#)² and Marco Calabrese¹

¹Polytechnic of Bari - DIASS, Italy; ²Polytechnic of Bari

Pa-6B: 4

Introductory programming by collaborative method "pair programming"

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