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3D Reconstruction of Cultural Heritage Sites as an Educational Approach. The Sanctuary of Delphi

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Abstract: In the field of cultural heritage, three-dimensional (3D) reconstruction of monuments is a usual activity for many professionals. The aim in this paper focuses on the new technology educational application combining science, history, and archaeology. Being involved in almost all stages of implementation steps and assessing the level of participation, university students use tools of computer gaming platform and participate in ways of planning the virtual environment which improves their education through e-Learning. The virtual 3D environment is made with different imaging methods (helium-filled balloon, Structure for motion, 3D repository models) and a developmental plan has been designed for use in many future applications. Digital tools were used with 3D reconstructed buildings from the museum archive to Unity 3D for the design. The pilot study of Information Technology work has been employed to introduce cultural heritage and archaeology to university syllabuses. It included students with a questionnaire which has been evaluated accordingly. As a result, the university students were inspired to immerse themselves into the virtual lab, aiming to increasing the level of interaction. The results show a satisfactory learning outcome by an easy to use and real 3D environment, a step forward to fill in needs of contemporary online sustainable learning demands.

Keywords: sanctuary of Delphi; virtual heritage; learning approach; higher education; virtual reality; Unity 3D

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1. Introduction

The Applied natural sciences address cultural heritage questions and problems, in the field, lab, and museum settings and include a wide array of topics, for the academia, society and education.

The virtual learning is a form of education that is increasingly being used in higher education in the developed world. However, the take-up and use of e-learning in developing countries is at a preliminary stage and the pedagogic content knowledge is even more demanding [1–4].

The COVID-19 pandemic has changed education forever. E-learning in schools of every level has been introduced and implemented in a fast and compulsory manner. Yet the need for virtual distance and e-Learning studies has been a hot debate and the education reformation is subjected to a definite and rather permanent transitional turn in the third millennium AD [5,6].

An interactive environment for creating and conducting simulated experiments makes a virtual laboratory. It contains the performance of experiments with domain-dependent simulation programs. In fact, a virtual reality technology can be adapted to create a virtual laboratory to simulate the processes and actions in physical laboratories. Alexiou et al. (2008) [7] argued that virtual labs present cheap ways for schools to obtain laboratories for all courses.

These remote laboratories offer users, especially teachers and students, learning experiences that might be impractical in physical classrooms. Users can design, develop, and achieve pre-determined experiments that simulate experiences and processes in real-world contexts. All students can be involved and participate, unlike the physical systems where only a few students can do the same and learn.

Bibliographic review has shown that software applications using 3D models in Archaeology have been increasing in recent years. Photogrammetry and digital technology applications in archaeology and cultural heritage enhance the ability to create faithful reconstructions of the ancient world and establish proper repositories [8–12].

There has been a notable tendency in adult education in recent decades towards the introduction of rich media, technologically advanced interactive environments in the classroom or online settings [13].

As these technologies continue to develop, many universities have integrated them into their pedagogical techniques, thus enhancing formal traditional classroom education [14]. Open Universities are examples in the field of Higher Education that use modern technologies with great success, like The Open University [15] and Hellenic Open University [16].

The benefits of interactive educational environments are that they allow access to the required information without time and geographical boundaries. Especially in the case of interactive simulations such as 3D virtual environments, one can try and repeat laboratory exercises several times without cost and risk. These affordances further benefit students' career development and academic performance [17].

The need for adopting tools and approaches such as the aforementioned is more imminent in the field of Archaeology, due to the need to observe, explore and experiment with tangible and intangible aspects of past cultures.

By studying the wide range of applications for communicating and disseminating historical archaeology, it is a fact that the emphasis is mainly on 'material' aspects of culture and the interpretation [18,19]. They typically focus on viewing archaeological sites, monuments, or artifacts, and generally material that is already available in physical form in museum collections or cultural sites and/or learn of their chemistry, technology, provenance [20]. Many times, these applications aim to help users understand their original form, but again the emphasis is mainly on the projection of the material and, to a much lesser extent, on the accompanying context [21].

Virtual characters often are added to the digital environment to add to the virtual environment as tutor and apprentice, daily life or rituals and historical events. This helps to simulate to the nearest reality the constructed learning output and a better understanding of the cultural elements of the virtual environment [22].

The potential applications of this technology are considerable. A variety of applications are already in progress, including education and training, therapy, marketing, and entertainment [23].

Despite the widely recognized capabilities of interactive 3D graphics and virtual environments in archaeology, the use of these tools in educational environments is still limited, while it is overused in other environments [24–29].

In the field of Archaeology, regarding university students' education, it turned out that there is no corresponding progress and most students have not used any education software during their studies. Undoubtedly, inhibitory factors are the costs to universities and processes of purchasing software. However, solutions must be found to enable students to use software for their education as well.

We have noted in our courses (but in other global universities too) a gap in the knowledge base of courses of history and archaeology. The theoretical presentations, even including PowerPoint presentations are not efficient. The issue that necessitated the study is explained from the lack of knowledge of archaeology students to deal with the sine qua non digital tools which form part of the archaeological sciences interdisciplinary field and the lack of instrumentation on their departments.

The theoretical learning framework with which we are working has simple descriptions of archaeological sites without an interactive procedure which strengthens the experiencing action with the help of virtual techniques. Within this frame and data, we introduce high school students with the digital terminology to the use of this ICT from home desk PCs.

The issue of learning from books and/or narratively in the classroom needs to be overcome and students need to tuned with modern information technology which has become part of everyday occupation; value should be assigned to this virtual tool applied to learning the environment and getting the sense of being there which is the objective of the presented application concept.

The triggering of our study came from the concerns regarding the laboratory learning techniques for archaeology science-based higher education students. The focus of this work is on the adoption of interactive 3D environments and game-based approaches to support the study of archeology and their effect on a formal curriculum. We have developed a prototype environment that integrates digitized 3D landscape, buildings and monuments from the Sanctuary of Delphi in a playful educational 3D environment following historical and environmental data. The virtual environment aims to educate archeology students through exploration and study of the archaeological site.

This research project has been inspired and designed to provide a substantial contribution on an international scale to Virtual Archaeometry and Cyber-Archaeometry [30,31]. Furthermore, we have set up an exploratory study, where we inspect the use of this prototype by Archaeology students in order to assess its usability and efficiency and to shed more light on the stance of students on the introduction of new technologies in classical sciences.

The present work exhibits the effectiveness of an interactive virtual environment for learning the cultural heritage through the reconstruction of the sanctuary of Delphi. Some examples of the related work of serious gaming in cultural heritage include Bellotti et al. (2012) [32] and Barreau et al. (2014) [33].

The current investigation aim is (a) to develop the 3D model and for students to become acquainted with the use of modern 3D imaging technology focused on the Delphi sanctuary, (b) to identify students' desired learning outcomes, (c) to reconstruct for first time a pilot model for the Delphi environment, and (d) to conduct an exploratory study.

Its innovation lies mainly in the development of some data of serious gaming in University education of archaeology and history students, on cultural heritage assets, and in the making together of the frame of knowledge that serves their needs. Moreover, the environment is not simulated with false virtual data but verisimilitude with accuracy and real data and accurately positioning objects and monuments, avoiding arbitrary settings making the learning environment closer to the real one.

The aim of the application is twofold; first to let students virtually visit an important archaeological site, and second to deliver to them the associated educational material whilst virtually 'being there' in a fun and exploratory way. There are many archaeology students worldwide, and even in Greece, that have not yet visited the site of Delphi, and would like to have this experience. Of course, plenty of media is available about the place and its buildings, but a presentation in a virtual environment has some advantages: users are free to explore the environment at their own pace and observe the constructions from the desired distance or angle. Additionally, it is more effective to learn about a place and its history when the information is delivered through a visual and interactive experience. Instead of learning the bulk of information from a textbook, students access on demand the educational media associated to the place they are currently located in the virtual environment. Along with the aim, research questions posed such as (a) which is the scientific contribution of answering such questions? (b) how will the academic community or professional use the results to further expand research? and (c) what the effectiveness of the proposed virtual environment for learning purposes is, together with questions related to the posed exploration questions during the implementation of the project (see end of Section 3), are important issues which have been satisfied.

The following sections unfold as follows: an overview of related work with basic theories, the rationale and design of a virtual educational tour in the sanctuary of Delphi, the virtual construction of the environment, the educational content, the exploratory study, and then, the results and conclusion.

2. Theoretical Background and Related Work

Prior to some related virtual archaeology applications, the works are usually discussed along with a theoretical framework. This tendency is worthy of modelling the methodology and learning outcomes and marketing, yet in practical terms following the traditional method (theory and experience) coupled with new technology has a desirable result.

Berthon et al. (2003) [34] introduced the "paradigm funnel" as a research tool and suggested how it could be used to produce enlightened analysis of complex literatures. They explore the use of classical Kuhn's (1962) [35] notion of a paradigm that focused on understanding the historical evolution of the natural sciences. Social sciences arguments of the paradigm—which may correspond to our chosen application—do not apply to our model [36], because any decision to reject one paradigm case study is always simultaneously the decision to accept another, and the judgment leading to that decision involves the comparison of both paradigms with nature and with each other [35].

The introduction of four levels of learning through the core assumptions, the analysis, the theory, and the empirical result (the notion of "paradigm funnel") in our case corresponds to the assumed efficiency of the learning model, the inquisitiveness to reach the correct answers, the ITC tools developed and the virtual observation.

On the other hand, according to the Mindtools theory (computer-based tools designed to promote higher-order, critical thinking), educational software must function as a tool for senior school students and further to university students, in order for them to develop critical thinking and acquire high level knowledge and skills [37,38]. Educational technology, or edtech, has revolutionized the classroom by improving learning efficiency and efficacy. Used wisely, edtech strategies help students develop vital critical thinking skills, and can change the paradigms of education. There are several specific ways in which classroom tech can help students develop their critical thinking.

A lesson plan making the most of edtech strategies might include a video lecture, a discussion on a virtual forum, and even an educational computer game. Teachers' questions to the class can help students develop their critical thinking skills by making them defend their answers. Online learning platforms like interactive Blackboard and Moodle are great for this because they allow instant grading of tests and quizzes.

A paradigm of an archaeology-archaeometry exam can become a learning experience when the software corrects students as they go. This makes students more likely to remember correct answers and encourages them to study harder next time.

In-class debates are excellent critical thinking exercises in lieu of traditional classrooms. With the educational technology using available software, teachers can get every student involved in the discussion by requiring them to follow (and learn) a designed procedure to get the right answer and know the use of buttons, use of every step in the virtual class. The process is more efficient, and students can repeat their learning journey; they absorb the essence of the value and meaning of algorithms and the archaeological part of the exercise.

Archaeology has already taken advantage of the continuous evolution of digital technologies in various ways. The use of ICT and Virtual Reality techniques in the field of Archaeology is generally termed Virtual Archaeology [39]. Archaeological sites, monuments and artefacts can be digitized in 3D, reconstructions can be created and presented using Virtual Reality techniques and the digitized content can be enriched with additional elements (e.g., virtual characters) and information which users can explore and interact with in real time.

In addition, the appropriate use of modern technologies to achieve the specific objectives of communication and promotion of cultural content is increasingly being studied, and this scientific area is called Digital/Virtual Heritage [30,40].

In the advanced needs of modern educational policies over the years, ICT has emerged as a platform that is seen to enhance the knowledge and skills of students in mainstream learning environments. Higher education should consider students' views and educational needs, which can contribute to better learning outcomes by actively participating in the design and implementation phases of the software [41].

It is important for students to learn to think critically and evaluate the knowledge they have before they take on functional and leading roles in society. The process of critical thinking as a basic learning function in adult education can offer higher education opportunities for an effective and lasting change in student lives [42].

An indicative example of virtual archeology was the project "Rome Reborn" [43] where a historically accurate reconstruction of a large part of ancient Rome has been recreated. Inside the rebuilt ancient city, visitors are just able to navigate and inspect the city from different angles without educational interactions. In some other similar applications, virtual humans were added to virtual cities [44].

In another project [45], the city of Pompeii was presented in a reconstructed form with many virtual humans walking around the city avoiding conflicts. In that work, virtual humans simply move and do not engage in historically authentic interactions. So, their presence just expands the atmosphere of the simulation making the environment 'lively'.

Mauricio Forte [46] describes the simplest interaction at the first level, between user and virtual humans, as a passive perceptual interaction where digital navigation includes walking and flying, where the user can see 3D or panoramic virtual reality archaeological sites from different angles. This level of interaction was the most common in archaeological reconstructions, but it proved to be disappointing for many users who were targeting a more dynamic engagement with the content [47].

The inclusion of gaming elements (serious games or gamification) in Archaeology is a further way to motivate students to engage themselves more in the subject, given that most of them spend time playing digital games in their free time [48]. A relative project was the creation of a serious game for the Ancient Agora of Athens. The aim of play was to help non-expert people such as students, tourists, museum visitors, etc., to gain simple knowledge about the Ancient Agora and its monuments [8,49].

Despite using modern virtual reality technologies and providing rich information about the content, these applications do not set general educational goals for university students. A lot of educational applications have been placed in museums as public installations, mainly for children to increase their interest through educational toys and activities in museum objects and their history [50]. Museums' authorities are mainly interested in finding new ways to deploy engaging and stimulating exhibitions within their establishment in an attempt to foster a wider appreciation and understanding of their exhibits [51] and/or apply augmented and immersive reality [52].

Lately, in the field of virtual museums the culture platform "Google Arts & Culture" [53] has collaborated with cultural institutions and uploaded history and heritage online. For the creation of virtual museums, a high-fidelity technology is used both in the digitization and in the presentation of the exhibits. Users can navigate virtual collections of collaborating museums and explore artworks and information about them. However, in the field of virtual museums, further research is needed on how to use virtual exhibits to educate students.

In general, there are only a few works that aim to evaluate the educational approach of virtual environments and serious games in Archaeology and study their effectiveness. For this reason, there is a need to further explore better practices and methods for the introduction of virtual environments in archaeological education.

One important factor to consider in Archeology students' education and at designing educational software is their age. University students are adults, but the University education system works based on typical and conventional education methods with presentations, lectures, etc. On the other hand, many students enroll in e-learning courses that continuously develop e-learning systems, which offer students enough learning environments [54].

In addition, the use of 3D virtual environments in e-learning adds a spatial dimension in which users can move within this environment [55]. As several university students are in a continuous learning process, it was considered that they have started to recognize the more efficient and useful ways of learning for their educational needs. Those students who participate in e-courses obviously have specific goals and expectations of their participation and often decide themselves what is important to learn. Moreover, according to UNESCO [56] "Adult education is any educational process, any content, level or method for adults, whether formal or not".

Due to advances in information and communication technology (ICT), it is claimed that distance education will act as a spark for a new global education revolution in schools aimed at cracking the hegemony of the education system focused on print and paper. Online learning environments that do not place specific distinctions between physical and virtual realities can be used to realize such continuous education change in distance education. Designing immersive learning environments that implement effective instructional design techniques based on an existing learning philosophy is a critical factor in the progress of distance education. Study is, however, being debated on the efficacy of distance education [57].

On the other hand, since the 2000s, e-learning, distance learning, virtual learning, Internet learning, and others, independent of which terms being used, they have commonalities:

1. The learner is at a distance from the tutor or instructor.
2. The learner uses some form of technology (usually a computer) to access the learning materials.
3. The learner uses technology to interact with the tutor or instructor and with other learners.
4. Some form of support is provided to learners [1].

Reportedly, the simulation design principles depend on research on students' learning and interactions with the experimentation tools in various learning environments, and in this aspect fits into the STEM (science, technology, engineering and mathematics) and STEMAC (STEM in arts and culture); involving the Computational Thinking (CT), the Engineering Education Epistemology (EEE), the Computational Science Education (CSE) and the integration of Arts and culture with STEM in education and more generally in learning and teaching approaches and learning objectives [41,58–61]. The new transdisciplinary and interdisciplinary field that emerges in pedagogics is much valued, in particular in the contemporary emergence from lockdown due to pandemic, but in reappraisal of working conditions too. Arts coupled with Science, Technology, Engineering and Mathematics (STEM) is the STEM with Arts (STEAM) and STEMAC (with culture). STEMAC introduces students and educators to a holistic approach in classroom. Surely, there is integrated rapprochement, which reinforces the fragmentary bridges and slight lack of coherence, between natural sciences and engineering and technology, and for humanities (art/culture). STEMAC removes limitations and replaces them with wonder, critique, inquiry, and innovation [59].

3. The Rationale and Design: An Educational Virtual Tour at the Sanctuary of Delphi

Delphi in ancient times was considered to be the center of the world, where in the famous sanctuary, dedicated to the god Apollo, the priestess Pythia gave many oracles [62,63]. The history of Delphi may have been known to most university students of Archaeology via university lessons, but it is not easy for them to visit the archaeological site and conduct in-situ research. The rationale and concept here is to make the Delphi sanctuary accessible via modern technology tools.

We have designed an educational application, taking into account that this refers to archaeology students, that offers a virtual tour at the Sanctuary of Delphi enhanced with learning material. The virtual environment presents an accurate representation of the site, created based on real landscape data and digitized or reconstructed models of buildings and artefacts. The environment includes rich educational material in the form of text, audio narrations and videos, that is associated with the respective places, buildings, or landmarks of the environment. Additionally, it includes a collection of more generic information about the place and its history in the form of frequently asked questions, which is periodically updated by experts based on new questions posted by students in the environment.

Thus, our application follows the educational approaches (serious gaming) of discovery learning, as students have to explore and discover the educational content, and situated learning, as the content is presented to them in a virtual representation of the environment that is the subject of learning. Finally, students contribute to the content by posting their own questions and remarks that are used to update and enhance the educational material.

In present pilot project, there is not a main story as in most games. Additionally, there are no rewards, badges, or points systems. However, here the serious games elements include (i) a first-person controller which walks through all the sacred road and near the 3D buildings and monuments, (ii) a personalized feedback. Answers are given by email (after few days) to students for individual questions submitted through the special form anytime during the virtual tour, (iii) Simulation. The real environment of the archeological site has been simulated and enriched with 3D buildings and monuments, (iv) The goal is learning. Serious games should have a purpose that is not entertaining and is almost always related to a specific aspect of education or training. The main purpose of the present virtual tour is to educate archeology students, as have been described in this section.

The application design runs as follows: (i) it is a single-user first-person Desktop virtual environment. When users connect to this environment, they find themselves located in the virtual reconstruction of the Delphi Sanctuary, (ii) then, they can freely explore the place in a walking metaphor using keyboard input, a technique familiar from first-person navigation in 3D games, (iii) the environment has been designed with appropriate colliders and obstacles to ensure that the user's motion is restricted to specific paths and to avoid users being trapped or disoriented, (iv) a virtual human (or NPC as it is termed in games) is walking around in the place to create a sense of a 'living' space and to motivate users to follow it and further explore the environment, (v) while users are approaching a place of interest, the associated educational material is visualized as a set of media annotations, and they can activate it by pointing and clicking on it, (vi) depending on the content, images, videos, or textual descriptions that appear in a floating window. The text is also narrated for easier access, (vii) finally, a short menu is available to the users to further support their activities. It allows instant transportation to designated destinations, provides access to the generic material, or displays a form for user-generated questions about the place and its history.

In present work, archaeology students from two University departments (University of the Aegean and University of Peloponnese, Greece) explored the virtual space of the Sanctuary of Delphi in order to gain knowledge of its buildings and history.

Innovation here was the concept of using virtual reality cultural heritage assets via ICT for educational purposes with the participation and interviewing of students in almost all stages of software implementation. Students involved in the research lacked in software design and programming knowledge. Although they were capable of the archaeology issues, just a few (10%) had visited Delphi. However, their involvement was continuous in the design and implementation stages of the software contributing to their critical thinking and included the following actions:

1. At the beginning they identified and delineated their educational needs, with discussion and answers to questions about the knowledge they would like to gain during their virtual tour of the space.

2. They evaluated the usability of the trial version of the software with the aim of improving its functionality and enriching it with more educational material.
3. In the latest software release for the research, they explored the archaeological site through virtual browsing and answered multiple-choice questions to evaluate the knowledge they have acquired.
4. They imprinted their impressions and made suggestions for further improvement, as well as for extending similar applications to other educational subjects.
5. The questions posed in the present concept are as follows: (a) how was the interaction between tutor and apprentices in the design and implementation? (b) how accurate was the virtual environment made? (c) what was the student participation and evaluation in the whole process?

4. Materials and Methods

4.1. Design and Implementation Process

The creation of a virtual environment of an archaeological site for educational purposes presents some unique challenges. On one hand, the presentation of the landscape and environment should be as accurate as possible to reflect the feeling of being in the actual place. On the other hand, the environment might need to be enhanced with virtual reconstructions that are historically valid and accurate and have a strong educational role in the application. Inevitably, in most cases, the historical monuments have been partially or totally damaged, others have been stolen, broken, and others have been moved from their original location. Many of the important findings are found in museums, while natural and other disasters as well as human interventions with additions over time alter the image of the site. One must carefully balance between enhancing the site with representations of the past to strengthen the educational value of the application and avoiding adding imaginary content that is not historically proven. The latter case is commonly found in reconstructions of the past in games and movies that provide inaccurate and misleading information.

Additionally, the design of an educational application must take into account the needs and preferences of the target group of learners. First of all, one must ensure that the learning content is appropriate for the students and their background knowledge. However, besides the content itself, its presentation and means of delivery is equally important. Therefore, the types of media that will be used, the order in which the various information will be presented, the association between the educational elements and the reconstructed space, and any challenges or playful elements that will enhance the environment need to be decided.

To ensure that the above-mentioned considerations will be discussed and incorporated to the design of the application, we adopted a participatory design approach that included archeologists, educators, developers, and representative students. The methodology that we followed for the creation of the application is the following (Figure 1).

First, we set up a multidisciplinary team with IT specialists, teachers, and representative students to determine the educational needs of the students, decide on the course material, and prepare the educational scenarios that will be supported by the application.

Then, we set up the environment using digitized models and reconstructions of parts of the site, we produced the educational material and we created a first prototype (demo) of the application.

After that, we set up an initial usability evaluation of the application with the involvement of the students, with the aim of improving and enriching the educational software.

The final step was the deep use and the final (summative) evaluation of the educational software.

Each step provided feedback on the previous one, improving and refining the design of the application.

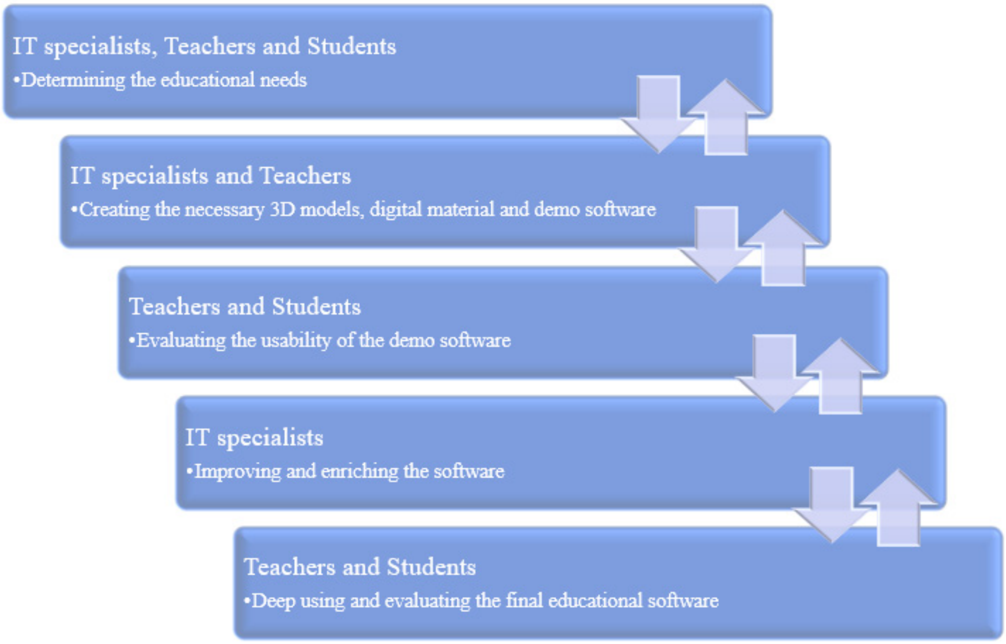

Figure 1. Methodology steps.

4.2. Construction of the 3D Environment

In order to build three-dimensional digital models of a site like an archaeological site, there are several tools and techniques that, with the appropriate and necessary input of real or even approximate data, outputs 3D models to different file types. The 3D models produced are the final product for importing to gaming engines for educational applications [64].

The 3D environment of the application presents the site of Delphi Sanctuary enhanced with reconstructions of its most important buildings and monuments. The data and models used were obtained from three sources, as explained in more detail in the following paragraphs: (a) the Delphi archaeological site and museum that provided models of the main buildings, (b) the use of photogrammetry technique and software for detailed terrain texture and additional monuments, and (c) GIS data for the terrain model. The application has been built in Unity, a popular engine for creating interactive 3D applications and games.

Initially, the digital terrain model has been imported from GIS data using SketchUp software with Oob Terrain add-on. The terrain was sized 2 km $\times$ 2 km. The texture of the terrain has been created with a series of photos taken from helium-filled balloon. The balloon (Figure 2) had rope-mounted fixed aluminum platforms equipped with a digital camera, Canon EOS 50D DSLR. On-site photos capturing required a flight plan of about 10–100 m [65].

Photo capturing from the balloon was performed as part of the Delphi4Delphi project [66], with the aim of collecting images suitable for the photogrammetry method using the Structure from motion (SfM) technique [67]. The main goal of the project is to capture detailed 3D images of the major archaeological monuments at Delphi and artefacts in the Delphi archaeological museum in order to contribute to the 3D reconstruction of the sanctuary in support of research, conservation, tourism and education [65].

For the creation of the 3D model of Delphi's archaeological site, more than 13,000 photos were taken, and the model produced by the laboratory of the University UCSD (University of California, San Diego, CA, USA) partner in Delphi4Delphi, had size ~4 GB. The 3D model was then simplified, and the final model was used in our Virtual Tour application (Figure 3).

Figure 2. The helium-filled balloon for aerial photography (Kingfisher Aerostat) (© I.Liritzis 2016).

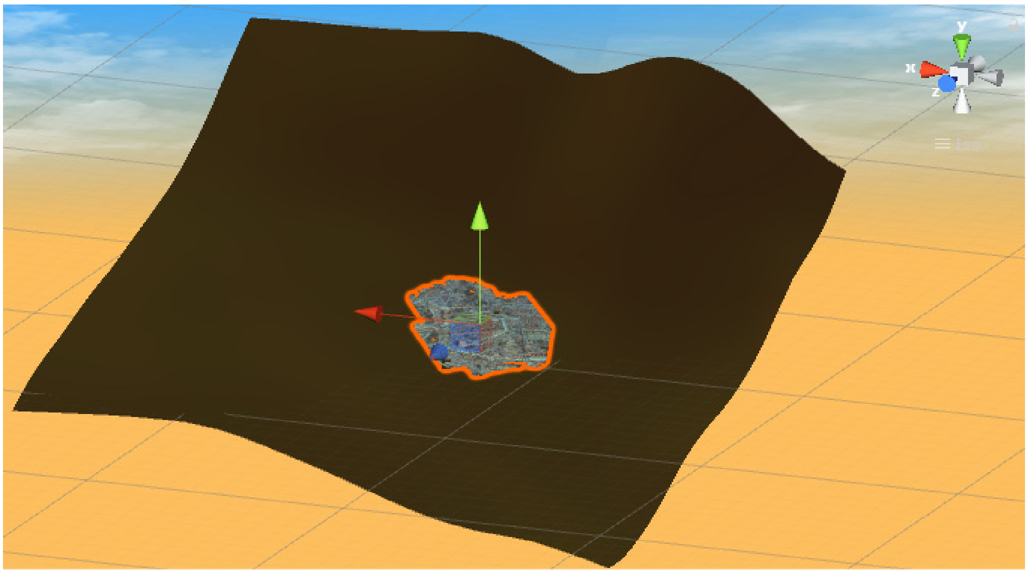

Figure 3. Terrain from Sketchup and balloon inside Unity 3D (© Authors).

From the web site of the Delphi Museum, 8 reconstructed 3D models of buildings were downloaded and placed along the sacred road (from the entrance of the archaeological site to the ancient theater), using a map of the French Archaeological School. The files used were free for both copy and redistribution, as well as for conversion to any medium or format, if they were not for commercial use (Figure 4).

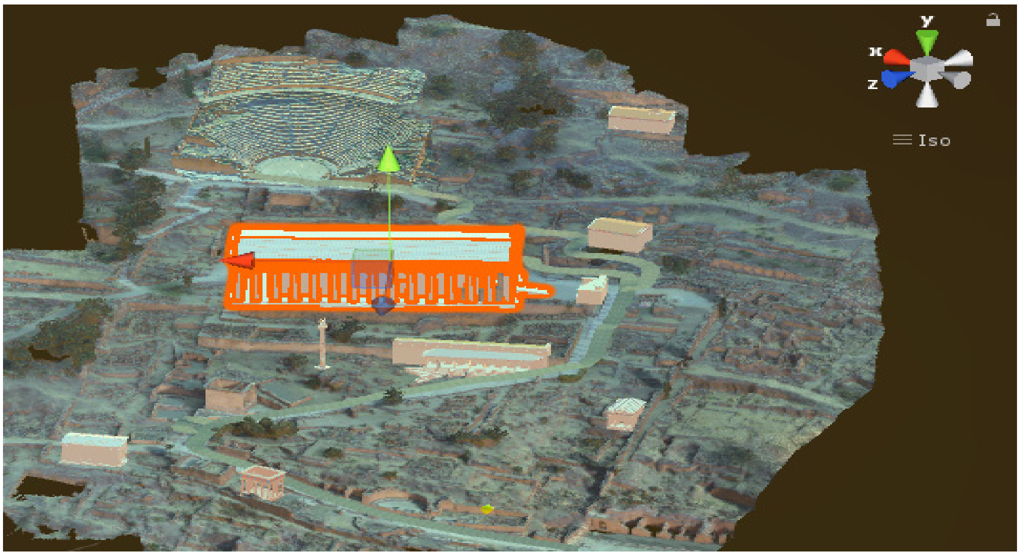

Figure 4. Import of 3D reconstructed buildings from the museum archive to Unity 3D (© Authors).

In addition to 3D buildings, the ancient theater and three more monument models were added to the virtual tour. The Omphalos symbolizing the center of the earth, the statue of the Charioteer (Iníochos), which is undoubtedly the most famous of the tributes to Delphi and the column with the Dancers.

To create the 3D models of the above exhibits from the Delphi Museum and also of the ancient theater, thousands of photos were taken and Agisoft's PhotoScan software was used to create 3D models of images using the SfM (Structure from Motion) photogrammetry [65] as part of the Delphi4Delphi project.

For the navigation in the virtual environment, Unity's First-Person Controller (FPS) was used. There was no time limitation in browsing, as a basic feature of a virtual space is that it allows users to move to their own pace [68]. For better contacting with the virtual space, a mini map was created in the upper left corner of the screen as well as a compass which can be activated for observing the orientation of the buildings.

Adding code to the software was done in a variety of ways. Small scripts were used, and especially the plugin for virtual coding "Playmaker". In summary, about 50 colliders were placed along the route, preventing the user from going out of the way, and 60 "triggers" detecting the player's movement and position in order to activate the corresponding scenarios (a free online demonstration is given in [69]).

4.3. Educational Content

Before the final implementation of the software, university students had the ability to test the initial version of the virtual tour and the educational scenario that would unfold. Then, questions were asked in an open discussion which was recorded about their educational needs, and how they could be satisfied with the software.

The students asked for information on how the buildings were constructed, the time they were constructed, the architectural style of each building, the reason for the location of each building, the orientation, the place of origin of the building materials, and if they had been taken, the archaeometric measurements that had been taken at the monuments. They also asked for some informative videos and the possibility of an audio narration of the information.

Some examples of this recordings are given bellow:

1. "It would be better to have questions at the end as a little evaluation. Many questions during the tour can be tiring".
2. "Badges and rewards I think are for younger ages. It is better to have more information about the buildings and archaeometric analysis if it has been done".

3. “Two or three informative videos would be useful for better understanding the history of the archaeological site during the exploration”.

The educational content was implemented with the contribution of the students and included beside the visual contact with the Sanctuary of Delphi, 3D reconstructed buildings and monuments along the route, information with texts presented in tables, recorded texts and compiled video clips, a menu of options for additional information, while students can ask any questions through a contact form (Figure 5).

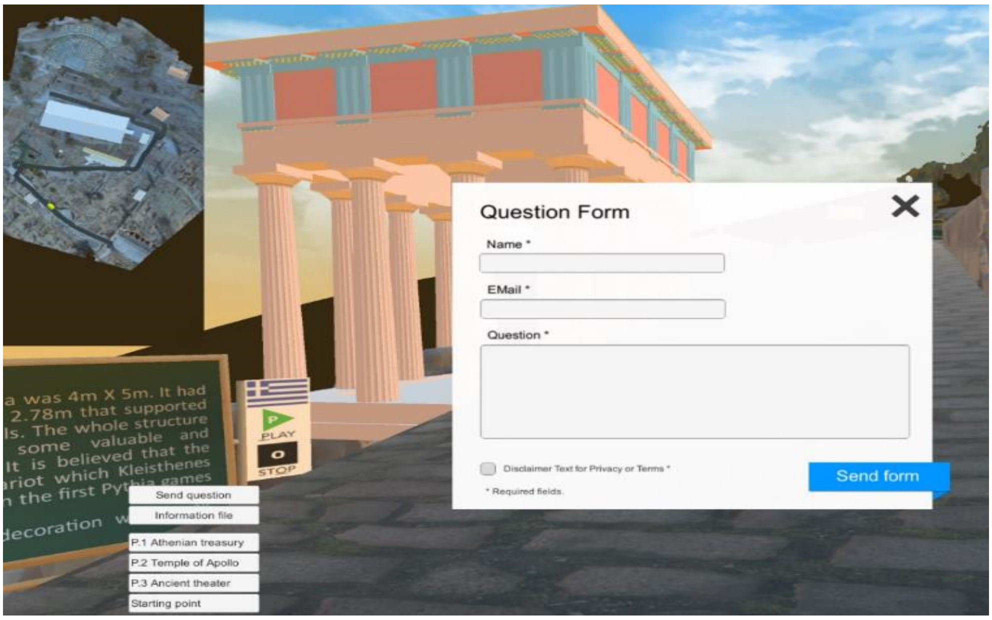

Figure 5. Final Software Version and Query Form of the route in the sanctuary (© Authors).

During the tour, students could learn about the history of the archaeological site and elements of architectural construction of the main buildings. In more detail, the educational content of the software contained the following elements:

1. Text: Hovering annotations with information at each educational point.
2. Audio narration: Students could activate audio narration for each information text.
3. Short video clips: Six video clips with historic information about respective interest points.
4. Compass: To observe the orientation of buildings.
5. Query form: Students could pose their questions anytime during their navigation. The answers were sent to students by e-mail.
6. Information document. A document with generic information about the history of the archaeological site and architectural constructions of the main buildings. This information file is updated and enriched to cover the student’s needs, as a feedback to their questions during their navigation.
7. Assessment questionnaire: Twenty multiple-choice questions created in collaboration with Manolis Stefanakis, Professor of Classical Archeology at the Department of Mediterranean Studies of the University of the Aegean.

4.4. Student Evaluation

We have set up a student evaluation to study and assess the educational benefits of using virtual tours, with the main aim being to contribute to the development and enhancement of Archeology courses. The aim was also to evaluate the level of knowledge gained and student involvement, as well as to help us uncover further ways in which digital technology could be used for educational interventions in Archaeology. A total of 112 university students participated in the research. More specifically, 29 undergraduate students of the Department of Mediterranean Studies of the Aegean University, 30 postgraduate students of the M.Sc. "Applied Archaeological Sciences" of the Aegean University and 53 undergraduate students of the Department of History, Archaeology and Management of Cultural Goods of the University of Peloponnese. The participants, who were all Greek, invited to take part in the questionnaires were mixture students of Archaeology during 2017. They were all Greek males and females of 19–21 years old for the undergraduates, studying in Rhodes and Kalamata, and 23–27 years old those from the MSc course, all coming from different parts of Greece.

Demographic analysis is the study of a population based on factors such as age, race, and sex. Demographic data refer to socioeconomic information expressed statistically, including employment, education, income, marriage rates, birth and death rates, and more.

The participants had to run the application, complete the virtual tour of Delphi, and then fill two online questionnaires.

The first was a knowledge assessment questionnaire to give quantitative data about the knowledge gained and the difficulty of the activity. Its role was also to raise students' attention while browsing the information they would have contact with on the route, but also to encourage students to read the generic information about the environment, as they knew that the assessment questions refer to the virtual tour and to educational material provided. The questionnaire consisted of 20 multiple choice questions.

The second questionnaire was about the students' general impression of the application and its individual elements.

The questionnaires and the subsequent data did not raise ethical issues and the code of ethics of the University of the Aegean was followed. The questionnaires were distributed via email, together with an explanation of what was being investigated and why. Students were asked to give their consent to participate to the research.

5. Results and Discussion

The knowledge assessment results were very satisfactory. The rating was from 0 to 20, with one point per question. The average grade was 16.5 and 75 of the 112 students (67%) had a score of 17–20. The chart below (Figure 6) presents the score distribution of the students. Although they explored the environment and studied the educational material without any help from a tutor, the average scores were quite high.

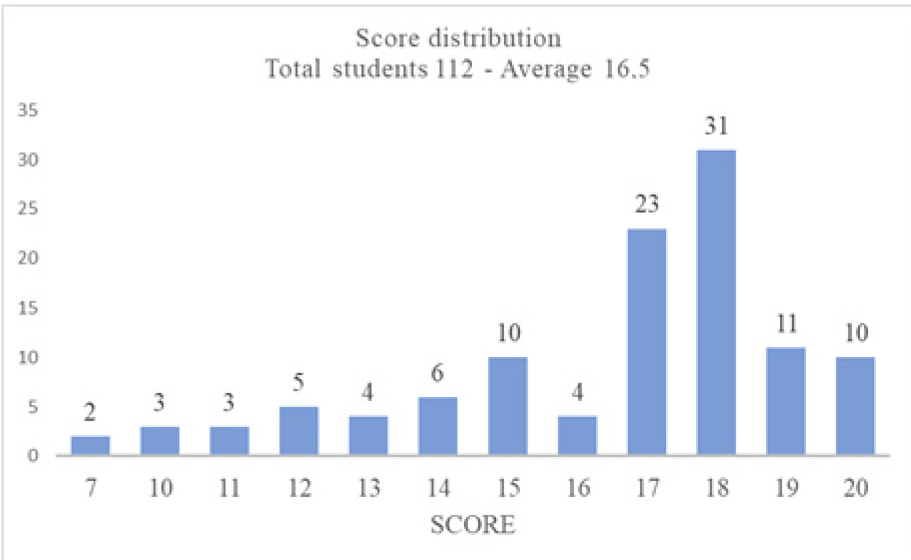

Figure 6. Score distribution of all students who participated in the survey.

The second questionnaire was the assessment by the students of the educational approach used in the virtual tour, and their suggestions for better practices for the educational software used in the research.

As far as the use of educational software is concerned, we noticed that very few students had difficulties installing and running the environment due to older PCs. Most students, however, did not encounter problems in exploring and finding information, and all students completed the virtual tour. Some minor problems mentioned in the interviews concerned 3D navigation difficulties in turns and crossroads.

The Temple of Apollo, which was the largest 3D model, was obviously of the greatest archaeological interest. It was important that most students found the virtual tour impressive and the liked the information posted along the route. Of all the students, only 17% (19 students) had used similar software during their studies.

Such educational software according to the students' views are useful for almost all courses of Archaeology, and the quantity of information has been characterized as satisfactory. Of course, it is not clear whether the satisfaction of the students is at the same level as the tutors.

Knowledge evaluation questions in the students' opinion were moderate to easy, and some very easy. This is also confirmed by the scores received. This was not an issue, because by enhancing the information file and by asking additional resources, the level can be increased whenever necessary. It was important that all students responded that they gained more knowledge after using the educational software as this was the main goal. Of course, some knowledge about the archaeological site, the architectural elements of the buildings, may have existed.

An interesting feature of the educational approach was the ability to pose new questions during the exploration. The goal was to interact with the tutor for information not provided in the software and to continually enrich the information base with answers as students make questions. Students responded positively about the usefulness of this approach, although many did not use it, while just few (5) called it indifferent.

All students confirmed the contribution of 3D space to acquiring knowledge and gave us reasons for which this is happening, although they were not asked.

> *"It clearly contributes to the acquisition of knowledge as the student acquires through the 3D representation a better and more enriched image for the archaeological site. Additionally, it is not tiring to browse or read short texts that exist in this space because knowledge is acquired using several media (image, video, 3D)".*

> *"It is an interesting point of view on how to acquire knowledge and it is a challenge in my opinion for everyone even with virtual tour, to explore the archaeological sites in their natural dimensions".*

> *"If the software had only pictures and information and did not have a 3D tour, it would be very boring. That almost true virtual tour was a great motivation for me to do this tour".*

Equally positive were the responses to the contribution of 3D reconstructed buildings to knowledge.

> *"Yes. Many buildings and monuments are totally damaged. With their reconstruction they are given a full view of the site and this is wonderful because you see the antiquity to come alive while our ignorance of their construction and decoration dissolves. A piece of history is restored".*

> *"Yes, what we learn in theory for how the temples were made of, we can see it live, I think it is more direct knowledge than to learn it theoretically".*

An apparently low percentage (23 or 20.54%) replied that the software has totally covered their needs. This number is however considered as "high". The majority, 80%, requested better graphics and animations similar to modern online and 3D games. Additionally, a possible tour through the buildings and generally outside the defined route would be interesting for students. Other equally interesting elements were the demand for music and sound effects, people of that time, and rituals representations.

Generally, there have been interesting answers which prove the need to ask students for elements that will cover their general needs by educational software, in addition to their educational needs.

In order to increase participation in the empirical research and to examine the role of software as an educational tool, a grading motivation to students was given by the lecturers, subject to completing their participation at the educational activities. This idea proved effective for increasing student participation, something that students admitted in their respective answers.

Examining the knowledge gained from educational software with multiple choice exercises is a topic that often creates disagreements. Most students (91%) were positive with that kind of tests, but it was confirmed that there were several contestations as to the outcome. However, that is not an obstacle to their use as any form of examination has its weaknesses.

Finally, perceptions were sought on the more efficient use of educational software. Students had no experience in educational issues and few of them (26) said that they did not have any opinion on the subject. However, there were several responses that were listed below, which shows that their perceptions have been affected by their participation (Figure 7).

QUESTION: How do you believe the use of educational software could be more effective;	N.o.S.	Rate
I don't know	26	23%
Combined with formal education	22	20%
As compulsory in curriculum	10	9%
More guidance - more teacher guidance	8	7%
With appropriate infrastructure in equipment	7	6%
With better graphics in software	7	6%
Training of students in educational software	6	5%
With greater interaction - fun	6	5%
By involving students in software design	5	4%
By teaching educational software	4	4%
Adapted easily to the needs of the lessons	3	3%
With more knowledge tests	3	3%
By teaching programming	2	2%
With better connection to the curriculum	2	2%
By teaching in groups	1	1%
Total	112	100%

Figure 7. Answers for more efficient use of educational software.

Although the inclusion of this virtual learning method into the formal curriculum in the class is ~37%, the inability to evaluate its effectiveness (23%) is explained by the new idea using computers and programming. This is confirmed by the low rates of involving them in the design, the graphics, and the programming. One should bear in mind that students are from the archaeology discipline rather than from positive sciences.

The quantitative and qualitative findings becoming clearer is related to the aims, and reverting to research questions is necessary to evaluate the results.

The archaeology students were inclined to learn more on the development of the 3D model and students became interested in the use of modern 3D imaging technology. The learning outcomes begin to emerge with a 16.5 average score and for 83% students not familiar with the software, the pilot the model and the exploratory study gave satisfactory statistical results on both quantitative and qualitative basis. That all students considered the virtual tour and the information posted along the route impressive is encouraging for future integrated implementation of similar approaches. Their desire to learn more about virtual reality, 3D modelling and in general the importance of applied sciences and IT to cultural heritage issues has been verified earlier with a cyber-archaeometry project [6].

The presented 3D model was made using proper measurements of aerial images with high resolution and a digital terrain of best simulation to the real one, accurately placing the various monuments, instead of a rough virtual environment for gaming purposes.

Such an accurate 3D model has value as a pedagogical activity. The levels of prior knowledge of students in the historical-archaeological environment in Delphi was inadequate and on the 3D technology there was little except only for some students due to the learning presentations in the archaeological sciences courses. Yet, there was not a clear knowledge of these two, which was shown when combined; it seems to pertain to a long-term retention of learning; in addition, the students have a sight of the instruments used.

Critical thinking has been shown on students' participation in the design and evaluation of the educational objectives and various details of the software, using a first version of the software. This is in line with the edtech and the theory of Mindtools, both computer-based tools, according to which educational software should function as a tool in the service of students, for developing critical thinking and to acquire a high level of knowledge and skills.

A traditional lecture serves an instantaneous knowledge which fades over time, on the contrary, the present model has a quasi-experiencing property remaining in time. This has been tested via electronic communication with the students again after several months and it was noticed that the information was retained by nearly all of them. Here, the edtech strategy included educational computer gaming and discussion. This demonstrates that there was merit in the use of the 3D model but also their active participation in the design and evaluation of the project is an added value in their learning outcome and their hands-on development of interdisciplinary works most needed in our high-tech era. Archaeology and cultural heritage research cannot advance without their link with natural sciences.

6. Conclusions

The project followed a methodology which involves the user's needs, the necessary 3D models—virtual environment of Delphi sanctuary, and evaluation from student users.

Amongst the most important results is that it has shown that students used the software directly without problems and participated in the virtual activities, focusing more on the educational object and the information material. It is proven by several applications that virtual reality devices (VR headset, Treadmills and Haptic Gloves) provide increased interaction. Another crucial result satisfying one of aims is that they have shown that the educational software must be implemented with the aim of allowing university students to use it with a simple, relatively modern computer in their own space. Once the needs of the learning object are met, it could additionally be possible to support the connection and use of various devices to increase virtual interaction.

It has been shown that the 3D laboratory space, play elements, 3D navigation and building reconstructions have captivated the students and increased their desire to participate in educational activities. It is also noteworthy that the quantity of information should cover the subject but should not be tiring. For students with more requirements, additional information and resources can be given in complementary ways.

Questions posed in the start of the concept regarding the reception of students of the novel approach in learning were more than anticipated.

Regarding the research questions posed it is shown that the scientific contribution to the above aims is the creation of a virtual tool for cultural heritage students in a versatile, robust, with educational value, manner. The effectiveness of the proposed virtual environment for learning purposes was handled efficiently, and served the purpose as a contemporary advancement in alternative ways of knowledge acquisition.

The grading motivation was effective, as well as the participation of students in the improvement and enrichment of the software, as they felt creative and were able to express their views on technology in which they have experience from various other entertainment software.

The prospect for the practical use and implementation of the results depends mainly on the will of the tutors and on the educational and economic policy of the university governance (including researchers, academics, policy-makers). Satisfactory learning outcomes resulting from student assessment and from their views are a high presumption of the usefulness of the research which thus has the potential of an effective scholarly contribution. Finally, the presented concept expands cyber-archaeology and the need of expensive and not-accessible instrumentation for recording fieldwork data, and the uniqueness of the project consists of an innovation which is expected to continue with other material culture and ITC methods for the university students of archaeology and cultural heritage disciplines. The latter answers another research question which implies the usefulness to the academic community or professional in using the results to further expand research and educational learning outcomes.

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