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RESEARCH ARTICLE

An adaptable multi-learner serious game for learning cultural heritage

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Abstract: The current study presents an adaptable light game engine, which is used to produce interactive educational settings focused on cultural heritage. The tool is implemented using inexpensive and open-source technologies. In this paper we first discuss the architecture of the application and we then present two games developed by using the proposed engine. The produced games are multi-user and support the collaboration and communication among learners and among learners and instructors. Learners earn marks, badges and certificates as they study the material and complete the quizzes. Various evaluation experiments have been realized to understand the suitability of the produced content in educational activities. The evaluation results of the authentic educational actions were quite positive and supportive by both students and teachers.

Keywords: serious game, e-learning, cultural heritage

1 Introduction

Nowadays, all the stakeholders in education enrich the educational activities with Information and Communication Technologies (ICTs). Different e-learning tools and ICT technologies are designed and implemented for supporting and extending educational activities in various domains. Currently, the design and development of successful digital serious games in many application areas, including education and cultural heritage, constitutes a new flourishing gaming industry (Dörner et al., 2016; Laamarti et al., 2014). A serious game is a game not primarily intended for entertainment but has a clear and carefully designed educational goal. "Seriousness" in serious games is related to the intended purpose of the game, the reason why it was created, and not to its content (Michael & Chen, 2005). Serious games are "toys" that have a clear and carefully designed educational goal and are not primarily intended for entertainment. Their main purposes are to train, investigate, or advertise (Breuer & Bente, 2010). A serious game has the potential to enhance the user's experience through multimodal interaction. Multiple modalities such as visual, auditory, haptic, and even smell can be incorporated into a serious game. For example, integrating haptic technology in a serious game can add a hands-on element to the learning experience in educational games. Also, digital serious games contain different media, which can be a combination of text, graphics, animations, audio, video, haptics, etc. Meanwhile, the interaction of the player with the game is done using customary interfaces such as keyboard, mouse, or Joystick or using some intelligent interfaces such as an eye gaze, movement tracking, brain interface, and tangible interfaces. The environment of a serious game can be either 2D (two-dimensional) or 3D (three-dimensional) or a combination of the two. In a serious game, virtual or mixed reality can also be used. It is noteworthy that a mixed reality includes both augmented reality and augmented virtual reality (Dörner et al., 2016). In addition, the determination of the player's current location (location awareness) is often allowed. From another viewpoint, a serious game can be mobile or not, single or multiplayer. Usually, a serious game for education is online (i.e., it is played over a computer network) (Freitas & Liarokapis, 2011).

Cultural heritage is a fitting domain for serious games. Games for cultural heritage can support the preservation of artifacts and their reproduction (Laamarti et al., 2014). Also, they can promote cultural awareness and allow for the admiration of artifacts. Players of serious games for cultural heritage can have more authentic and engaging experiences if interactive technologies are employed intelligently and with imagination. Such applications would better fulfill the fundamental aims of authentic learning and student engagement. Cultural heritage could greatly benefit from interactive technologies (Pantano & Tavernise, 2009) and gamification approaches.

In particular, various real-time interactive visualization/simulation of realistic virtual heritage scenarios can be implemented. Such virtual heritage scenarios are reconstructions of ancient sites, virtual museums, and cultural demonstrations.

Mortara et al. (2014) and Malegiannaki & Daradoumis (2017) reviewed serious games in the cultural sector and they identified and discussed the most significant challenges in the design and adoption of educational games in cultural heritage. Appification has also encouraged the proliferation of serious game Apps for cultural heritage (Sakkopoulos et al., 2015). Appification describes the rapidly widening shift from Web browsing to the usage of smart-phone Apps for Internet-based information access and e-services consumption (Kosner, 2012). We remind that Apps are applications created for smart-phones and tablets. It is clear that utilizing serious games for cultural heritage education, supports effectively the user needs and provides rich and engaging experiences. Cultural heritage is a domain that could greatly benefit from ICT technologies to highlight various aspects of it (Lazarinis, 2011; Lazarinis, 2012; Vocaturo et al., 2019).

Our study focused on the development of an adaptable multi-learner game tool for cultural heritage using free and cost-effective technologies. Educators can upload educational content, which is then displayed to the learners / players.

In the rest of this paper, we review relevant studies, describe the tool, and provide specific case studies and evaluations of the system.

2 Relevant studies

Teaching and learning of cultural heritage can be supported by various applications and systems (Malegiannaki & Daradoumis, 2017). For example, Archeoguide is a tool supporting personalized Augmented Reality tours and reconstructions of ruined cultural heritage sites (Vlahakis et al., 2001). A interesting prototype for a serious game was designed for exploring Rome (Djaouti et al., 2009). 'MuseUs' is also described as a pervasive cultural heritage serious game (Coenen et al., 2013). A design framework for designing serious games is presented in (Andreoli et al., 2017). The framework has been tested in the domain of cultural heritage where players have been allowed to visit a historical site and solve a puzzle.

An online multiplayer serious game, called ThIATRO, which helps students to learn art history, is discussed in (Froschauer et al., 2011). The player slips into the role of an art thief in a fictitious scenery. The avatar is controlled from a first-person view by using the mouse and the WASD keys. ThIATRO is implemented in *Unity Game Engine* (Nicoll & Keogh, 2019) while all the 3D models were designed with *Google SketchUp* (Chopra, 2012). The initial test results, with a small number of players though, provided some useful insights into the games and were positive towards its utilization in real teaching situations. Different puzzles and other short games are presented in (Bampatzia et al., 2016). The aims of these games are the promotion of the museum and the introduction of the museum items and themes.

The design process of a virtual heritage experience, for a bomb shelter built during the Spanish Civil War, is discussed in (Schaper et al., 2018). Wall projections complement the guided visit. The paper discusses the design process and the evaluation results. The main conclusion of the study is that supporting the exploration of a monument with multimedia material, helps the users to more actively participate in the exploration of the site. The paper focuses mainly on the lengthy design process and less on the actual technologies employed. It is clear from their work that designing even an approving tool for learning cultural heritage on-site is a quite demanding process. Augmented reality has a positive impact on new knowledge in museum settings as it was demonstrated through experiments and focused groups (Moorhouse et al., 2017).

Mortara et al. (2014) identified the diversity of cultural content, which varies from physical, or "tangible", cultural heritage, such as historic sites and buildings, monuments, and other artifacts (writings, poems, etc.). They reviewed some studies related to serious games in cultural heritage. They structure their analysis based on the following classes: (1) cultural awareness; (2) historical reconstruction; (3) heritage awareness (artistic/archaeological heritage, architectural/natural heritage). Cultural awareness games are focused on immaterial heritage including the language, customs, traditions, spiritual beliefs, etc. Historical reconstruction games focus primarily on the reconstruction of a specific historical period, event, or process which happened in the past. Games in the last category, provide immersive environments to help users engage more actively and to gain a more realistic understanding of the actual sites. The applications in the three categories include puzzles, strategy games, 3D reconstructions, simulation games, and adventure games.

Malegiannaki & Daradoumis (2017) analyzed 34 games. These games intend to enable

physical or virtual interaction with a cultural place and its objects. They identified various game genres and the settings in which they are appropriate. According to the study, the majority of the games promote learning, engages students more actively, and approximately half of the reviewed games provide social interaction through a multiplayer design. Open source tools have been used to preserve cultural heritage (Goumas & Lazarinis, 2013) and to feature local landmarks in effective and costless manners (Georgiou & Lazarinis, 2013).

The i-Treasures project (Dimitropoulos et al., 2018) deals with the use of advanced ICT technologies in the field of intangible cultural heritage education. A platform has been created, which provides different types of services for different types of users in intangible cultural heritage education. The paper focuses mainly on the evaluation of their proposals and not on the details of the applications. A mobile game that utilizes local history and cultural heritage in its storyline and content is presented in (Luiro et al., 2019). The game, which was developed with input from subject-matter experts, introduces local history through a narrated story in which the user must visit historical locations and characters in the town. Mobile games have been used in other domains to raise the importance of issues in a game-ish approach (Lazarinis et al., 2020; Papadakis et al., 2021).

A novel adaptive framework for the easy and rapid design and creation of serious game-like applications for learning full-body gestures (e.g., dance steps) by imitating the pre-recorded performance of an expert is presented in (Grammatikopoulou et al., 2019). Their prototype tool supports recording or parsing and annotation of motion capture data. Small-scaled experiments for the evaluation of the game have been contacted and a group of dance experts was asked to design and generate their own game and evaluate their experience. The feedback remarks were positive in all their experiments. A model for game-based learning in cultural heritage is discussed in (Vocaturo et al., 2019). The three tracks of the model are Challenge, Response, and Feedback. The model is elaborated in the paper and its suitability for the cultural heritage domain is analyzed. A project-problem-based learning approach for motivating technically skilled students to learn and appreciate cultural heritage is presented in (Chiu et al., 2016). The students were placed in an interdisciplinary environment, instructed to apply 3D design and 3D printing technologies to realize ancient drawings of buildings found in the Dunhuang Mural from the Tang Dynasty, China (618-907 AD). A WebAR application is built where the learner can directly interact with materials (Tan et al., 2019). The study showed that the WebAR and embodied interaction can enhance student's tangible learning experience and transfer knowledge between craftsman and student.

The above works show that game-based learning is beneficial for domains such as cultural heritage. Some works remain mainly on the design level and some offer simplistic experiences. A few other works employ complex digitization techniques and augmented reality to offer realistic digital replicas of the cultural heritage objects or to provide immersive experiences. Notably, these works are artifact-depended and resource-demanding in both the development and the deployment phases.

In our work, we focus on building an adaptable and engaging game, based though on affordable technologies.

3 Description of the system

The main goal of our work is to develop an affordable, yet engaging, serious game, which could accommodate different content, serving that way different learning purposes. The specific objectives of our work are:

(1) To develop an interactive application with game characteristics to support learning in the cultural heritage domain;

(2) To support active and collaborative learning among peers;

(3) To provide the ability to adapt the content of the application to accommodate different learning aims;

(4) To support multiplayer competitions for the exploration of the learning materials;

(5) To utilize mainly open source technologies and popular development tools to create an interactive application that is rich in content, interoperable, and can even run in limited-resource devices;

(6) To evaluate the effectiveness of the serious game with different learning settings.

Having explored the benefits and limitations of game-based and interactive applications developed for the cultural heritage domain, we reviewed the affordable technologies for interactive applications which could run on various operating systems. We concluded that HTML5 (Anthes, 2012) is the best candidate. HTML5 contains tags, like the "canvas", "video", "audio", which are suitable for the development of rich multimedia applications. The "canvas" tag provides a

method for manipulating the input from touch screens. HTML5 is almost universally supported in all operating systems without the need for additional plugins, in contrast to Adobe Flash. CSS and JavaScript are complementing technologies. A database is also essential for supporting the required adaptability. MySQL is selected as the most suitable for our purposes. PHP is chosen as the server-side language for implementing the communication channel between the server and the database.

Our system is developed in a 3-tier architectural model:

(1) The ***Presentation Level*** differentiates according to the user category.

Players (learners) sign in or log in and they initiate the exploration of their selected uploaded e-lesson or continue their last session, should an active session exists. Thereafter, they can navigate within the digital 2-D reproductions of the places of interest. The application allows learners to watch videos, study textual and visual learning material, access external web resources and answer questions to earn marks and badges and to make available new locations on the map that were previously hidden. Using a common form-based interface, teachers can upload images relevant to the site to be explored and specify and enrich various spots with learning material (textual descriptions, pdfs, images, video clips, external resources) and quizzes. The presentation of the material is adapted to the screen dimensions of a user's device. The presentation is run on the client-side, as all the technologies (HTML5, Cascading Style Sheets / CSS, JavaScript) are client-based.

(2) The ***Business Logic Level*** is implemented in the server.

PHP is used to handle the transfer between clients and the server which listens to the requests of the clients and sends back the desired data. The data projected back to the learners concern mainly their learning progress (i.e., their progress on the game) but also the progress of the other learners, in an attempt to increase the competition between the learners and make the application more engaging. Learners at any time are aware of their current location, the points and badges they have collected and the points of interest they have visited. Moreover, they may send emails to their peers and teachers or chat with their peers to collaboratively answer a question or a quiz. This feature may be limited if an instructor wishes to. Live chat is active only if the instructor permits it, in order to encourage collaboration or informative assessment actions. The rating of a learner and their peers are calculated and depicted in real-time to increase the interest of the users.

(3) The ***Data Level*** (i.e., the last tier) is implemented as a relational database employing the MySQL DBMS.

The learner login data, their age, their class, their progress (completed and ongoing courses), their marks, and badges are stored in database tables. The learning data are also organized using the relational database model to support the dynamic loading of educational settings. All the multimedia material (i.e., images, video, sound clips) is external to the database. Based on their origin, they are either stored locally in the server or on an external site. They are referenced in the tables either by filename or URL. Learners belong to one or more teams. Learners are registered by teachers and they are also assigned to teams. Teams can be differentiated per lesson. For example, a team for a specific setting could consist of learners L1, L2, L3, and another of users L4, L5. For another purpose, a teacher could assign learners L2, L5 in one team, and only L1, L3, and L4 in another team. That way different educational purposes could be accommodated.

Data are either entered by the teachers or gathered during the game and concern the learners. Through a Web interface, teachers upload the main background image (i.e., the main playing area). They visually define specific points on the playing area and associate a main textual description and an image of the actual place, a few more images with textual descriptions, video clips, references to external sites, questions, and quizzes. Not all of these categories have to be filled out with data, but they can surely enrich the user experience. Also, there is no limit as to the number of items per category. Once a teacher defines the points of interest and designates specific learning items, the tool projects them to the learners. The teacher also defines the marks per activity and per point of interest and the marks required to complete the activity. Teachers also register the learners and assign them to teams.

The second source of data (i.e., the learners' data) is also stored in the database. Each learner activity is marked as completed or not completed and thus the computation of the results is achieved in real-time. These results are also accessible to teachers who can monitor the progress of their learners. Selected data (i.e., the total points and the number of visited points of interest) are also available to the other players during the play. Email communications (i.e., questions, results, comments) between learners and teachers are also stored in the database. Chat data are not stored for privacy considerations. Teachers can monitor the advancement of the learners in real-time and can comment on their actions (e.g. on their answers) or provide help should they are asked for.

3.1 First instance of the game: the case of Ancient Amphipolis

A fully deployed instance of the game can be found online on http://users.sch.gr/boigia/sg. This lesson is about Ancient Amphipolis (https://www.britannica.com/place/Amphipolis), which is an ancient Macedonian (Greek) city. The initial screens inform the user about the aims of the game. The explanations are provided by an ancient philosopher cartoon (see Figure 1) and the complete setup reminds of ancient Greece. The menu options and messages are available in four spoken languages (Greek, English, French, and Spanish) at the moment, although the currently loaded materials are in Greek, as the participating teachers and students are Greek. However, material in any language could be uploaded and the English interface could be utilized.

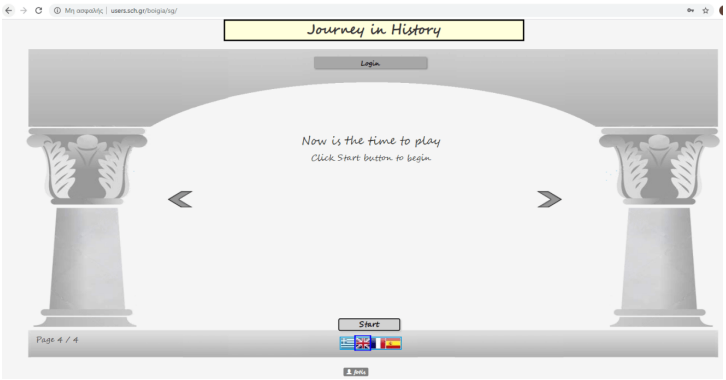


Figure 1 Initial screen with instructions as to the purposes of the game

The game shows a map (or an image) of a cultural or another site of interest. Teachers designate specific points of interest on the map and associate them with suitable learning materials. Figure 2 shows some of the points of interest for the specific educational setting. The Pegasus animated cartoon represents the position of the user on the map. Once Pegasus reaches a point of interest, the assigned items (images, text, videos, quizzes) are shown to the learner. The learner has to study the learning material to gain some marks and to answer the quiz to ensure that s/he understood the presented facts. Figure 3 shows an example of the learning items that are associated with a specific point of interest on the site. In Figure 4, the ancient philosopher acts as a visual assistant where he informs the learner about his current progress. On the right of the screen (see Figure 5), there is a mini-map where the position of the learner on the map is shown on a smaller scale. The movements and direction of the learners are also visualized on the mini-map.

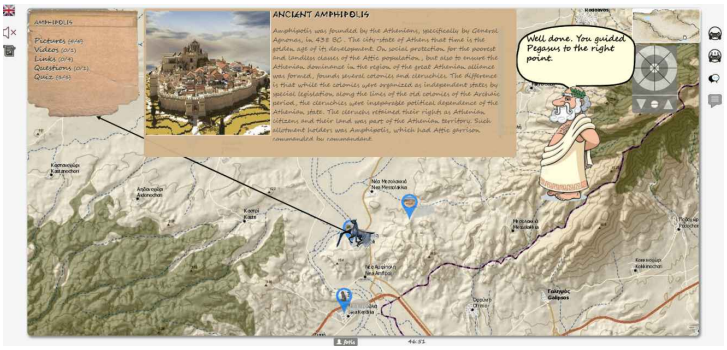


Figure 2 View of some points of interest on the map and related material

The credits gained by a learner (as a reward for each completed activity) depend on the complexity of the activity. For example, for each image visited by a learner, one point is earned. For videos and external resources, the learners earn two points. Learners also gain some credit points and badges for every activity they complete. When all the activities are completed, a student receives a virtual certificate of accomplishment.

With the navigation buttons on the right side of the playing area (see Figure 6), a learner can see its progress (see Figure 7a). They can also be informed about the progress of their peers (see Figure 7b). In both cases, the progress may be sent with an email to another person (e.g., the teacher, a peer of another team, etc).

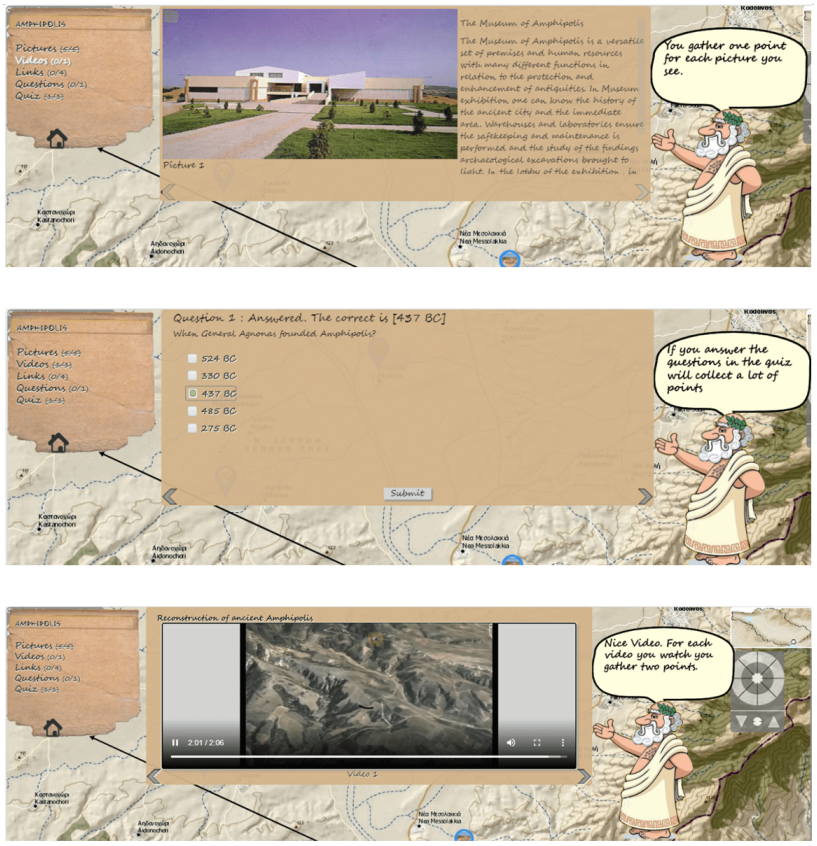


Figure 3 Examples of learning materials associated with a specific point of interest

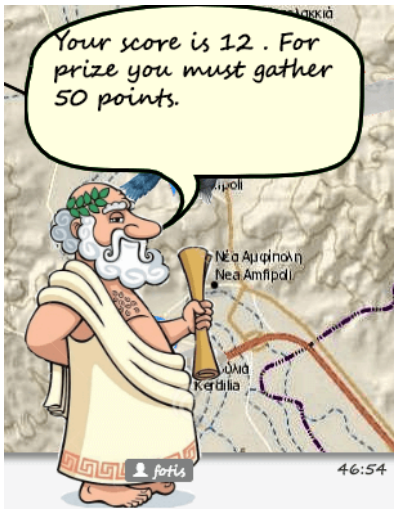


Figure 4 The visual assistant

Figure 5 The current location on the map in smaller scale and extra navigation buttons to visualize the learner's movements

Figure 6 Options for showing the own and team progress and for communicating with others

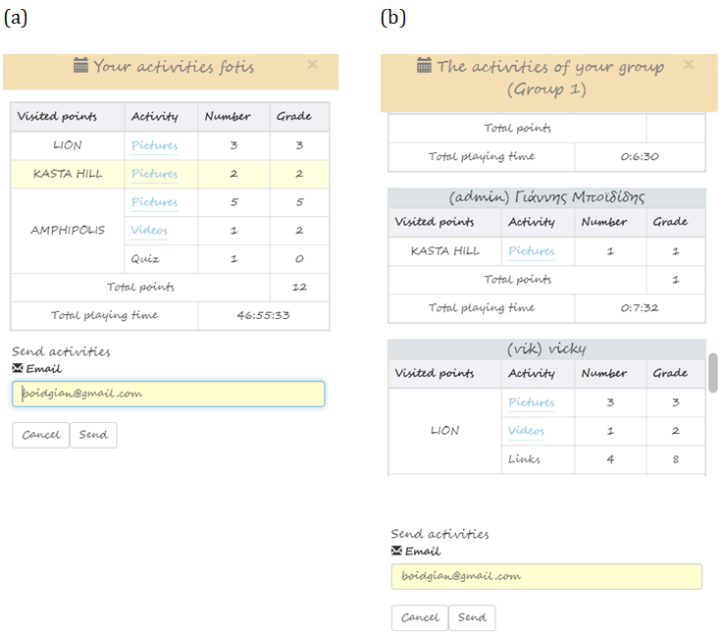


Figure 7 Own and peer progress

Figure 8 shows the chat and instant message options that are available in the game. Students and teammates can communicate and collaborate in case it is needed. Since the game has a mainly educative purpose, collaboration among peers should be encouraged and that is why we have not posed any restrictions yet. As expected, teachers can monitor the players' advancement and they can interfere should they consider it appropriate. Figure 9 shows the game executed on a mobile device using a web browser. Figure 10 shows a sample certificate of achievement available to the students who gain at least 50 points.

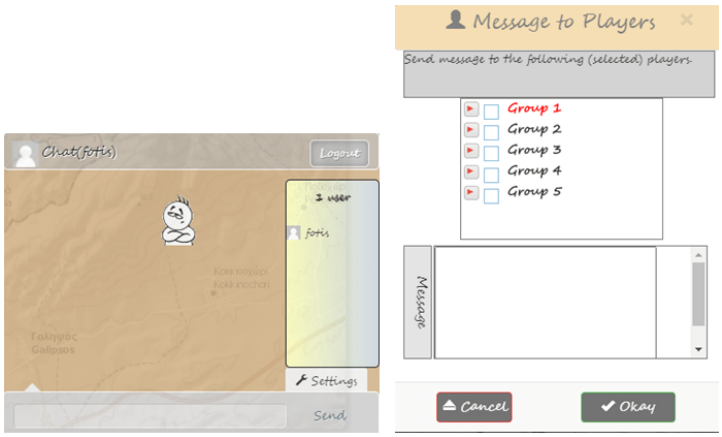


Figure 8 Chat and instant message options

Figure 9 The game is played on a mobile device

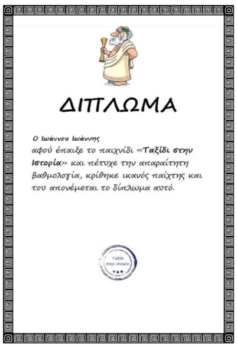
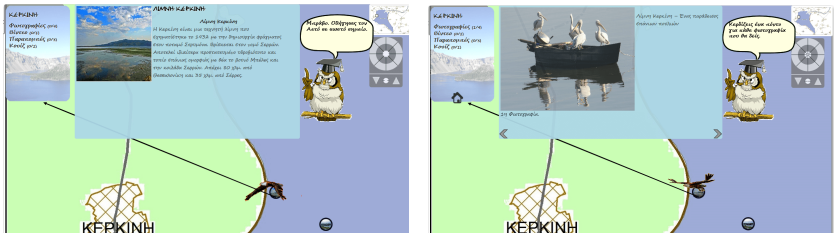


Figure 10 A sample of the certificate of achievement

3.2 Second instance of the game: The case of Lake Kerkini

The second educational setting concerns Lake Kerkini (https://en.wikipedia.org/wiki/Lake_Kerkini) which is a place of environmental and cultural interest. Figure 11 shows the main playing area and some points of interest. The virtual characters and the virtual assistant figures have changed to match the specific educational setting. Teachers can adapt these characters to match the lesson. This is a short course that has only two points of interest, and it was developed mainly for testing purposes.



(a) (b)

Figure 11 Lake Kerkini educational setting

3.3 Forming a lesson: The teachers' interface

All the lessons were designed under the guidance of domain experts such as history teachers, teachers of environmental topics, and computer science teachers. In total, eight experienced and computer literate teachers (4 history, 2 environment, 2 computer science teachers), formatively evaluated the application to verify its consistency and its suitability for learning activities.

The experts were available for consultation during the whole development cycle provide their assistance with the design decisions. This contributed at large towards the evaluation of the pedagogical aspects and the usability of the application in advance, before the implementation.

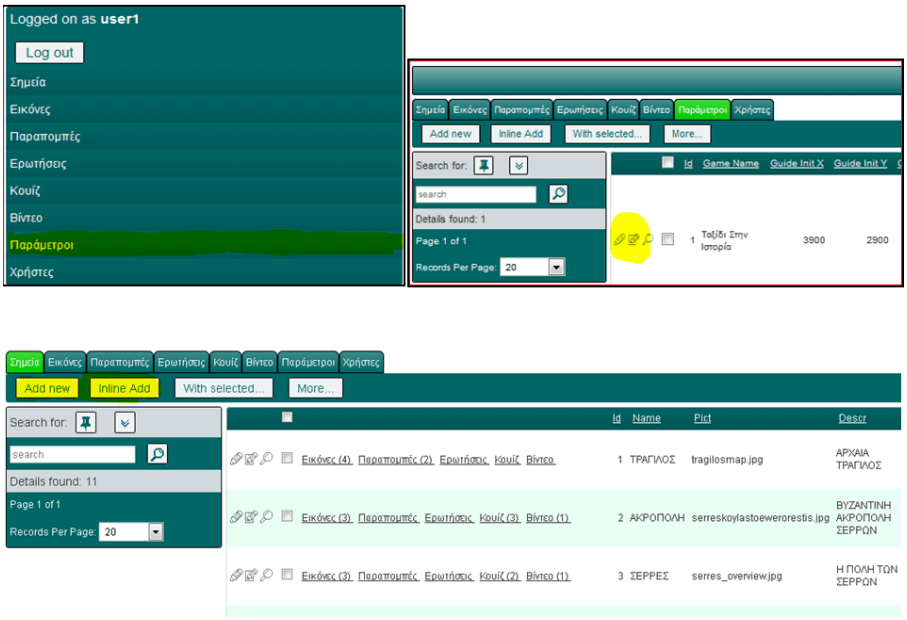
Figure 12 shows some examples of the interfaces that the teachers use to upload images of the main playing area and to define the learning material. They are mainly form data, but the content creators may see the results of their actions on a separate browser window and refine their selections.

4 Evaluation

Evaluation in educational technology applications is a vital issue and a quite demanding task. Several aspects need to be evaluated, varying from the user interface to the actual learner engagement and to the learning gain. Therefore, we run different evaluation experiments to appreciate the efficiency and shortcomings of the tool. The final version of the tool was made available during the second half of 2018. The evaluation test was completed between September 2018 and January 2020. The aims of the evaluation experiments and the demographics of the participants are described below.

4.1 Evaluation phase 1

The first level has already been discussed and it has been achieved with the aid of the eight domain experts, i.e. experienced teachers. 4 history teachers, 2 teachers of environmental topics,



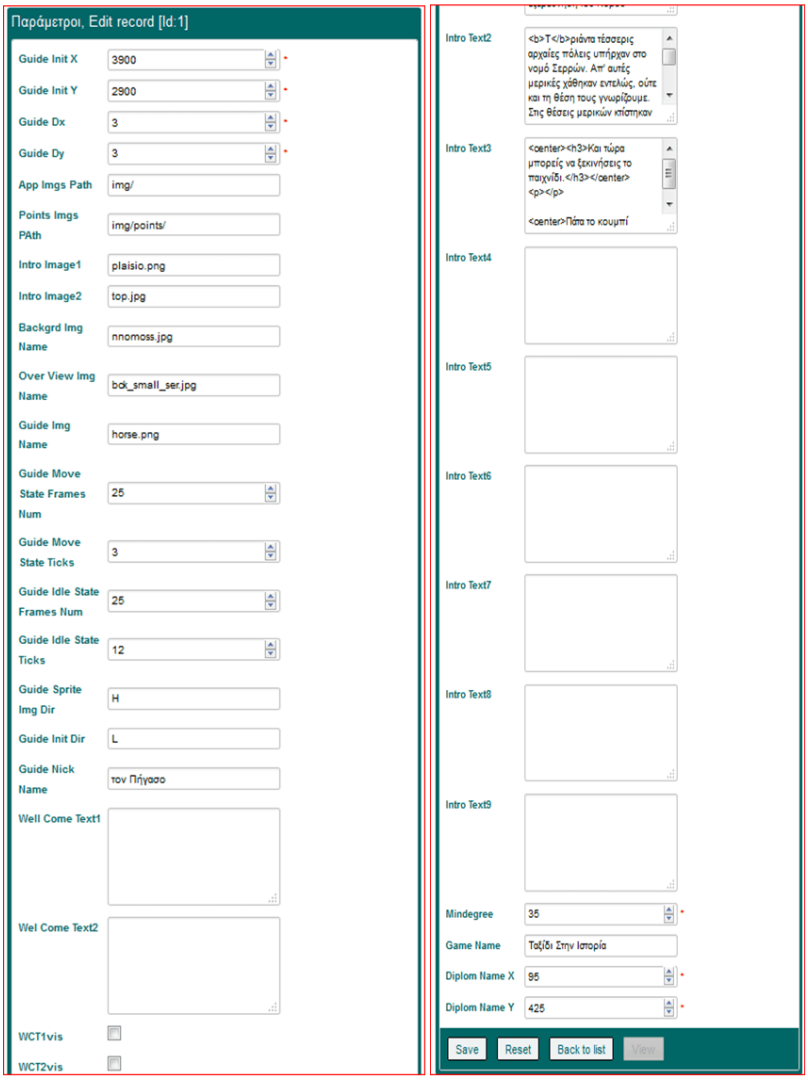


Figure 12 Lake Kerkini educational setting

and 2 teachers of computer science acted as advisors and evaluators. They all served in public schools, had more than 10 years of teaching experience and they were intermediate or proficient users in Web and MS Office tools.

Having explained to them the basic concept of the application, we provided them with non-operational interfaces to demonstrate our design. During this phase, they provided some useful advice that helped us to improve the model. During the implementation, once a new module was ready, they were asked to perform specific actions, e.g., upload a background image and define a hotspot. That way we could understand whether the interface was easy to use. The evaluators were rather positive towards our ideas and they found the game a suitable environment for learning purposes which is quite easy to use as well. Their suggestions in this information qualitative evaluation helped in refining the design and the appearance of the game.

4.2 Evaluation phase 2

In this second phase, we wanted to survey the opinions of teachers, who were not involved in the implementation. The Ancient Amphipolis educational setting was developed by two of the history teachers who participated in the first evaluation cycle. They worked for around six hours each to design the educational scenario, to gather the material, to form the quizzes for each hotspot, to fill out the forms, to assess the game for errors and inconsistencies, and to register the learners. Based on their experience, they considered the outcome to be the equivalent of a three-hour class, but with more fun and engaging nature. The game is considered suitable mostly for students aged 10 to 13.

However, the teachers believed that it could be used as approving learning material for older students in history classes, as its joyful appearance could improve the participation of the users.

After the development of the game, ten school teachers accepted to play the game so as to provide us with some feedback and to help us further realize its potential and deficiencies. All the teachers were history or philosophy teachers and they had at least six years of experience and adequate fluency in office and web tools. They all work with students aged 12-18 years old (i.e. secondary education).

All the teachers played the game individually at their own time, as it was more difficult to align them. On average, they spent 95 minutes on the game which is more than 2 class hours (45 minutes each). Considering that they are more focused learners with relevant and solid scientific backgrounds, we believe that indeed students would need more time to complete all the activities of the course. Then, we run a focused interview session to record the opinions of the teachers and to discuss potential improvements.

The first phase of the interview with each teacher concerned the usefulness and the friendliness of the system. All the teachers were very positive about the application. They shared their enthusiasm with us, as they found the application to be quite engaging for students. They also considered the application user-friendly, with a consistent and self-explanatory interface. They also found fitting the cartoon figures.

In the second part of the interview, we focused on the added value of the application. There was a unanimous agreement among the evaluators about the learning gain. They all firmly believe that such a game will benefit the learners and will help them to get a better understanding and a visual representation of the portrayed monuments. The game motivates students. The multiplayer characteristics such as the ability to see the progress of the other players in real-time, could enhance the competitiveness and thus the motivation of the students. The ability to add new hot spots, visual material, and videos strengthen the involvement of students. The digital objects could be updated at any time, which could lead to a prolonged engagement.

Next, we discussed the student age group they consider as more appropriate. They stated that the application could be utilized in any of their classes, although younger students could be more intrigued. Older students ($\geq$ 15) are more accustomed to fast-paced games and could be less interested. Students from 10-14 are a more fitting target group. In any case, they consider the tool to be a helpful addition to their teaching, far better than an MS PowerPoint presentation and of the static web pages they used to visit during their classes.

In the next part of the interview, we asked every teacher if they plan to use it in their classes. They were all positive, especially as it could run on the mobile devices of the students, so everyone could use it. Six of the evaluators will probably work on the application with the students in the school lab, so as to be able to monitor the process. Two of the participants intended to ask their students to use the game as homework. The last two teachers will be using the tool to implement a flipped classroom. Students will have to use the tool and to study the points of interest in a specific order. Then, they will have to discuss the topics with their classmates and the teacher during the regular class. It is clear that the application could support different instructional strategies and accommodate different learning goals.

At the end of the interview, we asked the evaluators to provide any additional comments they consider relevant. Those who had some experience with serious games argued that although the application could be a very useful addition to their classes, it would not hold the interest of the students for long. However, from the discussion, it emerged that if a number of different playing boards with different places to explore are developed, then it could be extensively used in their lessons. In any case, we do not aspire the tool to be an addictive game, but a tool that could support the learning procedure by motivating the students to joyfully learn about their history. The tool acts as a template that could be filled to create interactive material in a short amount of time. The created lessons are far more engaging, as it was ascertained by the evaluators, in comparison to MS PowerPoint presentations of other digital objects which are readily available or could be developed by the teachers.

4.3 Evaluation phase 3

The third phase of the evaluation is focused on students' opinions, observing their reactions, and record their suggestions. An electronic questionnaire was constructed for the evaluation of the game and it was distributed to 71 students who played the Ancient Amphipolis game in a school laboratory. The experiment runs in five different classes with students of different ages. Initially, it was explained to students how the tool works and what is the purpose of the game. The term "serious game" was introduced to the participants. 52.11% of the students were male and 47.89% were female. The ages varied from 11 to 15 (11 years old 15.49%, 12 y.o. 19.72%, 13 y.o. 21.12%, 14 y.o. 22.54%, 15 y.o. 21.13%), they were intermediate computer users and they all had extensive experience with computer games and they almost daily use desktops and mobile devices. Only 8.45% of the students played at least once a serious game in the past.

Then, we asked the students to use the game for 30 minutes and to explore any point of interest. The main aims of the experiment were for the students to study some of the learning material and then to complete the given questionnaire concerning the usability of the tool and the learning gain. At the end of the runs, 69,1% explored one point of interest and completed all the activities there. The rest 30,99% explored two or three points of interest. However, the average score of the first category was better as the time-consuming activities, e.g. video clips and quizzes provide more marks than images. All the learners sent at least one message to another player, all of them checked the progress of their peers and almost half of the players sent their results to their teachers.

The first part of the questionnaire concerned the user interface, the simplicity, the consistency, and the overall impression of the game. Table 1 summarizes the results of these questions. As it can be seen, the students consider the game easy to use, the interface simple and helpful, and the message informative. However, they have some objections about the attractiveness/appearance of the interface. Having extensive experience in computer games, the interface seems somewhat unattractive to the students. This is an anticipated problem and we plan to integrate some of their suggestions in order to improve the user experience.

Table 1 Questions related to user interface

Question	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
The feedback of the game is satisfactory	0.00%	0.00%	9.86%	35.21%	54.93%
The language used by the game is simple and understandable	0.00%	0.00%	0.00%	25.35%	74.65%
The symbolic representations used by the game are appropriate	0.00%	0.00%	2.82%	23.94%	73.24%
The interface protects the player from errors	0.00%	0.00%	5.63%	28.17%	66.20%
The messages during the game are informative	0.00%	0.00%	0.00%	7.04%	92.96%
The design of the game is appealing	0.00%	12.68%	11.27%	14.08%	61.97%
The help at the beginning of the game is useful	0.00%	0.00%	14.08%	28.17%	57.75%
The player must remember many things regarding the operation of the game in--order to proceed in the game	84.51%	15.49%	0.00%	0.00%	0.00%
In general, the game is easy to use	0.00%	0.00%	0.00%	0.00%	100.00%

Table 2 summarizes the answers of the students concerning the learning process and the additional value of the game. The students agreed or strongly agreed that such an approach is motivating and even more interesting than studying a book or viewing a PowerPoint presentation. The learning outcomes are more concrete and transferable and the collaboration and competition features are important.

At the end of the questionnaire, students had to describe the most positive and the most negative feature of the game according to their opinion and to suggest any improvement they considered necessary. Concerning the most negative, all the students identified the somehow simplistic user interface. The following list summarizes the most positive aspects of the game in descending order of popularity:

Table 2 Questions related to the learning process

Question	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
The learning approach of the game is interesting	0.00%	0.00%	12.68%	16.90%	70.42%
The information the game presents to the player is appealing	0.00%	0.00%	0.00%	28.17%	71.83%
There are no details in the game that distract the player from the essential--learning content	0.00%	2.82%	5.63%	26.76%	64.79%
The game has action options (e.g. quizzes) related to learning	0.00%	0.00%	0.00%	0.00%	100.00%
The game motivates the player to seek more information on the subject--being traded	0.00%	0.00%	0.00%	25.35%	74.65%
The game supports the transfer of learning outcomes to the real world	0.00%	0.00%	14.08%	28.17%	57.75%
Collaboration among the peers is an important feature	0.00%	0.00%	0.00%	0.00%	100.00%
The ability to see the progress of the peers is an important feature	0.00%	0.00%	0.00%	0.00%	100.00%
The process of learning through play is more engaging than studying a book	0.00%	1.41%	2.82%	16.90%	78.87%
The process of learning through play is more engaging than following a--PowerPoint presentation and direct instruction	0.00%	1.41%	2.82%	19.72%	76.06%

(1) The ability to see what other students do;

(2) The existence of images and videos which helps students to get a better understanding of the subject;

(3) The setting with the Pegasus and the Philosopher was fun.

Various amendments have been proposed which however aimed at transforming the game from a pure educational game to an action game. Some suggestions which could indeed be integrated are:

(1) the selection of different personas;

(2) the ability for the users to define their own names;

(3) the ability to form teams dynamically;

(4) the ability to share learning content. Some more intriguing suggestions include the ability to zoom in and out, the integration of google maps at least in a separated window, and the ability to explore the monuments in 3D or as 360° panoramic images.

Overall, the students seemed very accepting of the new learning approach. They enthusiastically spent all the available time in the game without any complaints. They could explore the game without any help and they were focused on gaining a high score. This was observed in all the participating classes. These observations, along with the responses of the students and the teachers in the previous evaluation setting, are quite positive towards our ideas.

4.4 Evaluation phase 4

In the last evaluation experiment, we focused on the actual learning gain of the students. We randomly selected 30 12-year-old students, who have not participated in the previous experiments, into two groups. The first group used the game and the second group attended a class with an MS PowerPoint presentation and direct instruction by a teacher. Both groups were taught the same learning material. A shortened version of the game (with only one active point of interest) was available to the first group to explore. The second group was shown the same material using a presentation. At the end of the educational activity, both groups had to complete a short test. They were then shown the teaching material and approach applied on the other team for comparison reasons. The same teacher acted as an instructor in both groups, to be a constant in our experiments.

Both teams had 30 minutes. Then, they had to take a 10-minute 10-question test. The average score of the first team who used the game had an average of 8.6/10, while the other team had an average of 7.33/10. Running a one-tail t-test shows that there was statistical significance (p is 0.029479). The minimum test mark in the first group which used the game was 7/10, while the minimum mark in the second group was 4. In fact, there were 5 students in the second group with scores 4/10 and 5/10. Asking these students why they think they performed not as high as it would be expected, they admitted that they were not as concentrated as needed during the lecture.

At the end of the test group 2 was shown how group 1 was educated with the aid of the interactive environment. All the students of group 2 complained and argued that the game would be more interesting and they should have used it as well. Group 1 preferred the game over the lecture given by the teacher. However, some noted that during the lecture they could ask for an expert opinion by the teacher, which was not available during the game.

5 Discussion

In the previous sections, we presented an adaptable application for developing interactive multi-learner serious games with the main focus on exploring environments of cultural or

environmental interest. We presented the aims of our research and we exhibited the features of the application through two learning settings. During the implementation, a group of domain experts evaluated our designs and helped us in refining the application. They keenly endorsed our ideas and supported the implementation of the work, as they considered such a tool as a valuable teaching service.

The Ancient Amphipolis educational gaming was developed with the aid of the two teachers of the first phase of the evaluation. For a 3-hour interactive course with gaming characteristics, each teacher worked for approximately six hours. Most of the time has been consumed in gathering the learning material and deciding on designing the main points of interest. This approach would be used even if they wanted to integrate the material into some presentation software. Adding transition effects or other interactivity would also require additional time. Using our tool, once the material per point of interest is ready, it may be promptly uploaded. So, the time of developing an instance of a serious game using our, unsophisticated, gaming engine is comparable, if not less, to the time needed to provide a digital lesson using an office tool.

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The evaluators suggested some improvements which would make the environment more appealing and more adaptable. Some of these suggestions have been integrated into the new version of the system, have been used in the final testing phase.

Overall, the evaluation experiments produced positive and useful remarks. If we compare our application with other serious games, we can argue that our work can be adapted to serve various educational settings in a short time. Some of the other games might be more appealing but the content is hardcoded and so they have a quite specific learning aim and they are dedicated to a sole educational topic. Further, they are more expensive to build. Comparing our tool with applications like Scratch (Resnick et al., 2009), which can be used to build powerful games, it is clear that both environments have different purposes and advantages. With our approach, we focus on making learning content more interactive and fun to explore. With Scratch and other alike tools, programming is taught through the development of interactive applications. Further, the educator has to be competent in coding, while in our case content creators simply design an educational scenario that they realize through the completion of a few web forms. There are quite a few environments for building educational games (e.g. Puzzlemaker, Edpuzzle, Kahoot, etc.) but the content that is created is more simplistic and of different nature than in our work.

6 Conclusion

This paper presented a tool that acts as a template for developing short interactive e-lessons. The system can be customized with new materials and playing areas. Teachers can upload the main image, define points of interest, associate learning material (text, images, video, questions, quizzes, and external references) and define the marks for each activity. Also, they can define the users, team up the users, monitor the progress of the students, and provide assistance during the exploration of the cultural or another environment. Users may collaborate and communicate with peers and they can also compete with them by inspecting their performance.

Once they reach the required threshold, they get badges and certificates of achievement. The evaluation experiments showed that we achieved our research aims and we managed to build a low-cost interactive and engaging serious game engine.

The presented light game engine could be used to produce games for other domains. For example, for exploring the internal organs of a human body or the main components of a motherboard. In the future, we plan to run more tests using the updated version of the system, with different learning content and with various student groups to further realize the potentials of the application.

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