Interdisciplinary Design of an Educational Applications Development Platform in a 3D Environment Focused on Cultural Heritage Tourism

Stavros Vlizos[1,4(✉)], Julia-Anna Sharamyeva[2], and Konstantinos Kotsopoulos[3]

[1] Ionian University, Corfu, Greece
vlizosst@ionio.gr
[2] National and Kapodistrian University of Athens, Athens, Greece
jamsharamy@arch.uoa.gr
[3] University of Patras, Patras, Greece
kkotsopoulos@upatras.gr
[4] Amykles Research Project, Sparta, Greece
research@amyklaion.gr

Abstract. This paper is intertwining the technology, education and public archaeology sectors in a case study approach of the archaeological site of the Sanctuary of Amyklaion, an important center of human activity in ancient Sparta, Greece. The creation of an innovative digital platform for the development of educational applications focused on cultural heritage tourism with the use of extended reality and gamification elements is presented. The applications are designed to be managed by a central documentation platform in a 3D environment produced by the digitization of the archaeological site, the excavation and archaeological finds. The main goal in the creation of this platform is to enhance the experiential learning of visitors of the archaeological site and the involvement of communities in the production and consumption of knowledge through new media, using educational methodologies and a human-centered ambient intelligence approach.

Keywords: Amyklaion · Digital humanities · Mixed reality · Augmented reality · Ambient intelligence · Gamified education applications

1 Introduction

In recent years, archaeology has unprecedently crossed its academic boundaries, forming interdisciplinary collaboration opportunities to further research regarding the preservation and presentation of archaeological data, and the interaction of cultural heritage sites with their communities. Particularly the technology sector has broadened the spectrum of possibilities offered to cultural heritage managers in overcoming challenges characteristic to ancient sites, while the education sector is crucial in providing methodologies for public archaeology programs.

M. Shehade and T. Stylianou-Lambert (Eds.): RISE IMET 2021, CCIS 1432, pp. 79–96, 2021.
https://doi.org/10.1007/978-3-030-83647-4_6

This research proposes an innovative approach to the design of scenarios for education applications on a digital platform using augmented and mixed reality in archaeological sites, guided by quantitative and qualitative methods. The goal is to transfer the experiential learning experience through focused methodology of the excavation of the archaeological site of the Sanctuary of Amyklaion in Sparta, Greece, to students and "cultural" tourists. The section State of the Art will cover the theory on the interdisciplinary collaboration between the broad archaeological, technological and educational sectors, and highlight some approaches that will be used in the following research. Subsequently, the section Methodology will add substantially to our understanding of focused quantitative and qualitative methods that are utilized in the creation of educational scenarios for augmented and mixed reality applications.

In the main section of the Case Study, the reader will find, after a brief presentation of the archaeological site, a detailed description of the augmented reality educational platform that is currently under development, with emphasis given on the individual components that the platform integrates for serving its purpose. We elaborate on the educational scenarios incorporated in the platform and we demonstrate via a showcase example the platform's operation. To ensure the usability of the platform, we carried out a user survey in which we record the familiarity of end users with the technologies being embedded in the platform as well as their needs with respect to the services offered. The results of the user survey along with their implications to the deployment of the platform are thoroughly discussed in the Results section, where we also outline the educational scenarios that serve the project objectives. We conclude the article (Conclusions and Future Work) with a summary of the work in progress and we outline open issues in this ongoing research that merit further study.

2 State of the Art

Over the last few years, a close cooperation has been developed between the technology and culture sectors to create useful tools for the preservation and presentation of cultural heritage [1, 2]. Augmented reality technology has opened new avenues and created unique opportunities in the field of culture. Visitors now have the opportunity of a unique and novel experience in museums and cultural heritage sites as through augmented reality they can "process" exhibits and cultural goods in another way [3, 4]. Thus, the public is actively involved in history through the provision of virtual stories and information offered by museums and cultural institutions to enhance its experience [5, 6]. The educational community has also developed a keen interest in the use of electronic tools to further educational goals. A three-dimensional virtual environment can be used as an educational tool bringing people from different locations to interaction with the purpose of gaining knowledge [7]. Moreover, gamification creates new approaches to historical experience as the visitor becomes actively involved. The concept of gamification, in using game design elements and mechanics in non-game or serious contexts to engage people and enhance learning, problem-solving and action

[8, 9], is directly related to the possibilities offered by the digital space. The digital in its various forms, websites, applications, etc. dominates as a medium in almost every aspect of human activity. Flexible, malleable, without the limitations of the analog space, it also draws most of human creativity. It is very important, however, not to turn digital into an end, for that would widen the gap between the digital and the analog/physical world. In that direction, gamification is viewed as a valuable concept applied within a variety of contexts [10] to varying degrees of success [11]. Serious or applied games with historical content are one of the most popular forms of public history and, in combination with their historical content choices, become particularly effective as narratives experienced in informal settings [12]. Gamification applications are essentially a new form of historical text that offers the opportunity to change the ways in which history is perceived by the public, as they possess properties that precede their content and simultaneously shape it [13].

The holistic approach of the following case study combines studies about interactive narratives through augmented reality [14, 15], the prospect of creating fun experiences with AR [16], the self-determination of the applications' user via gamification [17], the transition of extrinsic gamification types of users to their relative intrinsic types of users [18], the enabling of active participation and learning processes through new realities [19–21], the creation of narrative scenarios and rich material for the enhancing of the user's learning [22–24] and the logic of creating alternative narratives in case the user chooses it [25, 26]. Finally, there are also studies that cover parts of the suggested framework, e.g., the HoloMuse, that offers a complete experience interaction with museum exhibits through mixed reality [3].

3 Methodology

A case study approach was used in the archaeological site of the Sanctuary of Apollo Amyklaios which involved the collection and analysis of primary data specific to this site. For the purposes of better evaluation of the community's acquaintance with the proposed new technologies, quantitative and qualitative methods were combined in the form of a questionnaire and accompanying short interviews. To combine the two kinds of data needed the options of parallel data gathering and integrated design of the survey were chosen, providing more insightful understandings [27, 28]. The specific methods are explained in detail in the respective section of the Case Study below and the subsection Community Inquiry.

On the development of the scenarios on the digital platform, bibliographical research was conducted. Bruner's [29] theory of discovery learning was decided as the core pedagogical philosophy. A key element of this theory is the belief that for the subject of the learning process to discover new aspects in an already pre-existing form of knowledge, it is necessary to have stimuli. Through an exploratory process the essential understanding of new knowledge will be achieved. As a continuation of the above understanding, the constructivist theory of knowledge approach was selected.

According to the theory, learning effectiveness is inextricably linked to one's ability to creatively understand and assimilate knowledge, through a process of interacting with various stimuli [30]. Proponents of this educational model believe that subjects of the learning process, when actively involved in the receival and construction of information and knowledge, are then able to understand it in depth as well as maintain it [31]. In more detail, this approach highlights the effectiveness upon learning processes of play, discovery, mobilization of the subject's imagination, and interaction and interactivity with the information provided [30]. Specifically, the parts missing from traditional learning environments are what the research attempts to cover using augmented and mixed reality and gamification techniques.

4 Case Study

4.1 The Archaeological Site of Apollo Amyklaios

At a distance of 5 km south of Sparta in the Peloponnese, Greece, and on the hill of the church of Hagia Kyriaki, near the settlement of Amykles, lie the remains of the ancient Sanctuary of Apollo Amyklaios [32, 33]. According to ancient written sources [34], the sanctuary constituted the most significant religious center of the Lacedaemonians in the ancient era. The site is host to several monuments from a variety of chronological periods, most notably the unique Throne of Apollo, a temple in the form of a seat for the colossal xoanon (wooden statue) of the Olympian god Apollo, that can be undoubtedly considered the most impressive and yet enigmatic architectural monument of the end of the Archaic period. Besides the important architectural and material remains, the archaeological site is connected to major historical events and the cultic festival of Hyakinthia, celebrated annually in honor of local hero Hyakinthos and Apollo [35]. Thus, the archaeological site has sparked the interest of various distinguished scholars since the late 19th century and since 2005 it is the subject and raison d'être of the Amykles Research Project [36]. The archaeological site of the Amyklaion incorporates a series of values and offers significant benefits of scientific, historical, educational, aesthetic, local and economic character to society but also to the individual groups connected to it, for example the neighboring settlements, the scientific community, the local students etc. The evidenced continuous use of the location since the Early Helladic period, ca. 2200 BC. until today, expresses the timelessness of the archaeological site, while the presence of the church of Hagia Kyriaki since the 19th century is a component of the past and present social life of Amykles, connected to the collective memory of the inhabitants. Finally, the place offers a multi-sensory experience as it is located in a panoramic position with rich natural beauty and a vast view to the south valley framed by the mountains of Taygetos and Parnonas. All these characteristics that make the hill an archaeological, religious and natural landmark need to be shared in a direct and experiential way with its community and visitors [35].

However, there are many limitations in that direction: the site faces different difficulties, some common to other cultural spaces, such as the lack of original material due to its reuse in local constructions since late antiquity, the constraints of its rural location and ongoing systematic excavations which inhibit visitation, as well as the fact that the site remains largely unknown or indifferent to the public despite its importance. In general terms, the antiquities and the past of the area have always been a point of reference for the inhabitants, to the extent that they influence and define, to a certain extent, the modern cultural life of the area. Nevertheless, their connection to the present is mainly limited to attracting tourists, to the sterile invocation of a glorious past, and to the sometimes-unhistorical highlighting of specific aspects of a long-standing local history. These challenges present an opportunity to research existing and create innovative ways of resolving obstacles that cultural heritage sites in general may face.

4.2 Augmented and Mixed Reality Educational Platform

The present project aims to highlight the above issues and focus on the community and visitors of the site, enabling them to interact in a direct way with the monuments, the environment and the cultural heritage, and to utilize their cultural content by cultivating intuitive understanding and learning. The architecture of the digital platform for the creation of education applications consists of a central documentation platform with 3D support (CDP), an educational narrative applications development subsystem (END) and a mixed reality training modules development subsystem (MRT). The 3D content produced from the digitization of the archaeological site, the excavation and archaeological finds is imported and managed from the central documentation platform. Dynamic virtual educational narratives that intend to enrich the visitor's experience through their presentation via augmented and mixed realities are followingly developed by the archaeologists in the two subsystems of the platform. Thus, the platform will be able to unite the digital and analog cultural space through gamification interventions that activate the physical space through imagination and creative composition. Through a programming interface (API) the content of the CDP and the processes of the END and the MRT are offered to an augmented reality application (AR-App) for mobile devices which support ARCore and to a mixed reality application (MR-App) designed for HoloLens 2. With its human-centered ambient intelligence approach utilizing the location awareness from GPS location and beacons, it will enhance the experiential learning of visitors of the site, such as students and cultural tourists and demonstrate the idea that archaeological sites and their material should not only be the subject of scientific study and then just admirable by the public, but actively engaged with.

CDP, END and MRT are web applications and were developed with NET Framework. Unity, a popular cross-platform game engine, was used for presenting the documentation of 3d content utilizing its WebGL build option. Unity and C# were used for the development of the AR-App in iOS and Android and for the MR-App in HoloLens 2. One of the final goals of the project is to tangibly share the results and

methods of the research with the people of the archaeological service and other cultural institutions, so that it can be utilized in other heritage sites through customization.

4.3 Proposed Objectives

Considering the prior research and outcomes of similar digital platforms, and the results of the brief analysis of weaknesses and opportunities present in the archaeological site of the Amyklaion, some key principles were proposed for the design of the educational scenarios and the user interaction of the educational applications. These principles can be sorted in two main categories, the first relating to operational objectives specific to those who will create the educational scenarios in the application environment, and the second is objectives pertaining to the way the content can be presented to the visitors.

The operational objectives include (1) the ease of configuration and detail modification of the scenarios in the END and MRT subsystems so that they can be adapted to different heritage sites through the proposed methodological analysis of their visitors, and (2) the utilization of the ambient intelligence features (GPS, beacons, etc.) of the educational applications accustomed to a heritage site so that to improve the personal experience of the user.

On the side of the content presentation modes, objectives involve (a) ensuring that the visitor can get acquainted with the key narratives of the site, (b) the use of gamification elements where possible in the learning process and (c) the use of comprehensive content for people of all social and age groups to cultivate genuine interest towards archeological material as cultural goods capable of conveying meaning to everybody and not exclusively the specialists. Finally, (d) special care must be taken to preserve interaction with the natural environment, for a direct and grounded, albeit multi-sensory, communication with the traces of history.

The development of the digital platform for the creation of educational applications followed an interdisciplinary route. For the past two years, during the excavation seasons the archaeological site, as well as specific excavation trenches have been digitized as 3D models with photorealistic textures with the use of photogrammetry terrestrial photographs and unmanned aircraft systems (drones) at regular intervals (per excavation strata). The generated 3D models of the site were imported into the content management system (CDP). The descriptive and three-dimensional information about the excavation and the findings that was stored in the CDP constitutes the basic material for the development of the educational applications. These applications take the form of a narrative with game elements utilizing augmented and mixed reality and positioning technologies (GPS and beacons). In its subsystems, the CDP allows the creator to incorporate georeferenced 3D models of the archaeological site, excavation strata and findings and cross reference them along with supportive material, such as text, images, video, audio, quizzes etc.

4.4 Community Inquiry

For the purposes of this stage of development of the educational applications in the digital platform environment, to deduce the level of user familiarity with the new technologies and based on that to fine-tune the platform's usability, a survey in the form of a questionnaire and accompanying short interviews was chosen. A focus group of 24 participants visited the archaeological site accompanied by the research team. The participants were locals who had either visited the site multiple times prior to the survey or had knowledge of it through proximity. Before the conduction of the survey, the participants were self-guided around the site with the help of temporary informational signs, placed by the research team as part of a separate study (not outlined here) regarding the best placement of the necessary permanent signage of the archaeological site which is currently in its final stages. The questionnaire contained closed questions and the accompanying interview expanded on the answers providing some open questions so as to combine the quantitative and qualitative methods of research and get the insightful results needed in this phase of the case study.

Beside demographic data, the survey included questions on the familiarity of the participants with smart devices and their type of use, as well as with the technologies of virtual, augmented and mixed reality, establishing a baseline of the participants' rudimentary expertise, or lack thereof, on the subject matter. Regarding the level of familiarity with the use and trends of smart devices, 29.17% assessed themselves as being moderately and 37.50% as being very familiar. This self-assessment seems to reflect the number of smart devices the partakers own, with 37.50% possessing 3–4 devices. Among users of smart devices, the majority (85.71%) reported needing them for both personal and professional reasons. Coming to the subject of VR, AR and MR technologies, 66.67% had knowledge of at least one prior to the survey, with the most well-known being VR (75%). From thereon, the survey focused on the use of the above-mentioned technologies in archaeology and cultural settings and their perceived usefulness in the visitors' experience and learning. Of all partakers, 75% agreed to the new technologies assisting in the visit of an archaeological site and the learning process. Regarding the possibility of experiencing the Amyklaion using extended reality technologies, the participants reported being moderately (18.18%), very (31.82%) and extremely (40.91%) interested.

Finally, the participants were asked to contribute their thoughts on which monuments of the Amyklaion would be most advantageous in their presentation through the new technologies or should be highlighted and what other parameters they believe are important for the research team to consider. Regarding the best monuments to engage digitally, out of the 24 members of the survey, 21 indicated the Throne of Apollo as the most representative of the site and the one hardest to fully understand architecturally without any visual aid. Following, with 18 mentions, was the Hyakinthia festival as a good opportunity to witness and better understand the rituals of this extremely important to the ancient Spartans annual fest. Of average interest were the altar and the *peribolos* with 16 and 10 mentions respectively, probably since they have been recently partially restored, while the remains of the Roman and Byzantine periods gathered the least suggestions (4 and 6). In addition to the monuments, some participants felt that the excavation process itself and its most important milestones through time are

interesting and vital, even, to communicate through the digital application. In this context, the wish for seeing the findings of the excavation in situ, by way of 3D models of pottery and metal objects, came up as a companion mode of learning to visiting the archaeological museum that is situated in the center of Sparta. The interview yielded satisfactory results as to its initial goal, since the participants opinions and directives coincide with those of the research team: most of the participants stressed the importance of having a complete overview of the archaeological site, as well as learning from a specialist, i.e., an archaeologist, but in comprehensive terms for visitors. Additionally, many concluded that they would find the use of quizzes a fun and memorable way of learning, echoing, unbeknownst to them, the concept of gamification [8]. Finally, highlighting the landscape alongside the archaeological content was also a point that the participants thought of as ideal. The survey findings are used to better understand the end user's needs and to modify the user experience designed in the platform deployment.

5 Showcasing Current Results

To better showcase the features and use of the digital platform and its subsystems, a sample of two of the developed scenarios is followingly presented, the first one for the educational narrative applications development subsystem (END) and the second for the mixed reality training modules development subsystem (MRT).

Considering the key thematic units of the archaeological site, mentioned above, and used for the placement of informational panels throughout the site to facilitate a plain visit (Fig. 1), the research team devised an educational scenario about the Hyakinthia festival. The creator can set and categorize each task and subtask by difficulty, duration, degree of immersion, as well as define which positioning technology will be used for each one to activate (Fig. 2). In this scenario (Fig. 3), the visitor is presented with information about the festival while being in the starting position near the church (Fig. 3, 2.1). After the completion of quizzes (Fig. 4) and static tasks related to learning about the phases of the festival, they are invited to gain "rights" or an invitation to "participate" in the Hyakinthia. To do so, with the guidance of the AR-App, they must complete the task of preparation, which is comprised by subtasks of locating items they need. One example subtask is the discovery of the hidden flute by solving quizzes and following hints towards its location near the altar (Fig. 3, "Flute" point near the center). A beacon corresponding to the item has been concealed there and once the visitor approaches it during the specific scenario, it is considered found and collected. The same applies to the rest of the items. Once all the subtasks are complete, the visitor can then "participate" in the Hyakinthia festival. They are prompted to go towards the Throne of Apollo (Fig. 3, 2.2) and once the application device is positioned correctly (with the use of GPS position and a marker on the sign), corresponding to the preset viewing point of the location where the temple was situated, the visitor is rewarded with a 3D model of the Throne (Figs. 5, 6) represented in antiquity and augmented in real size.

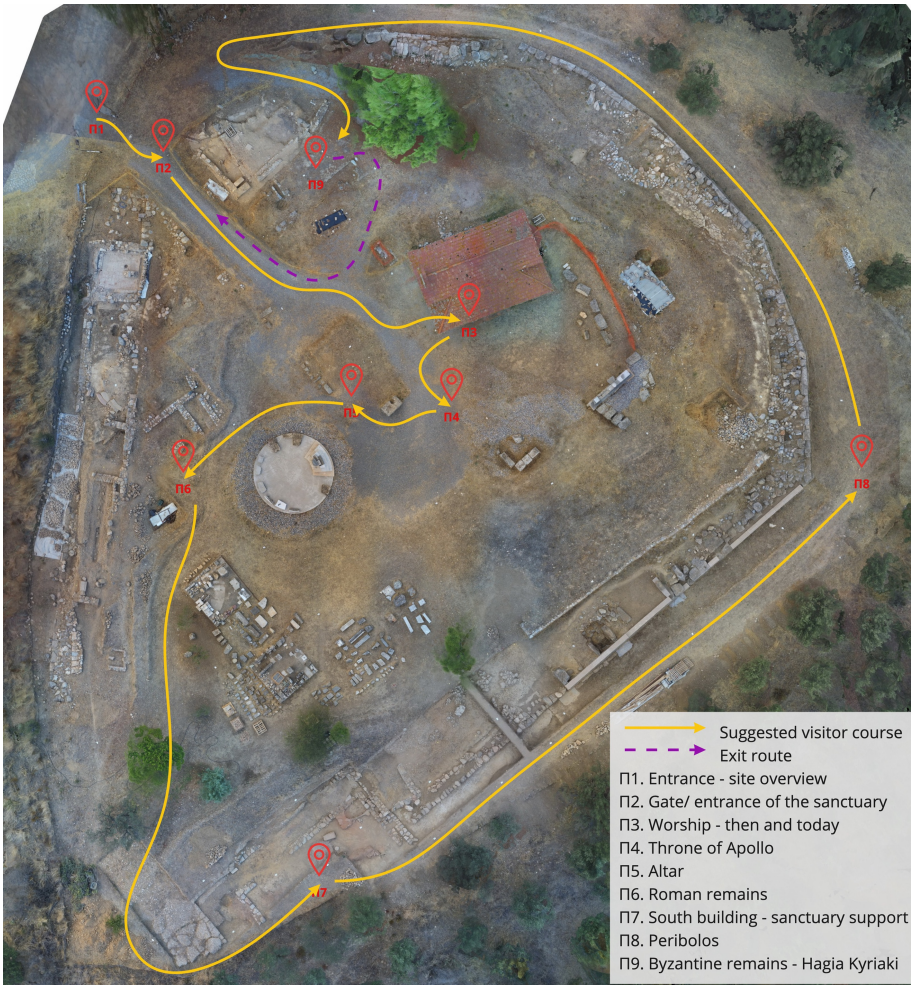

Fig. 1. The main stations of a visit to the archaeological site, covering all thematic units

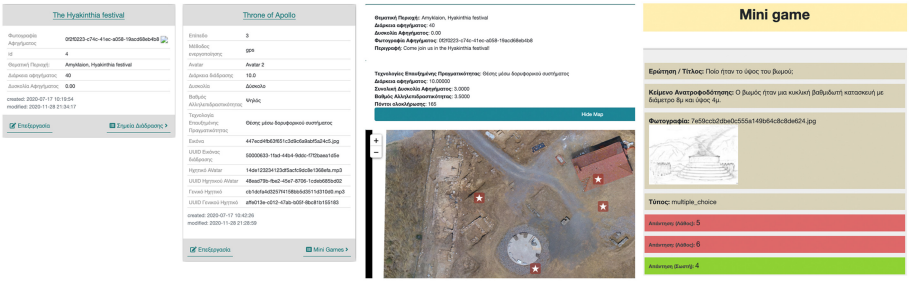

Fig. 2. The digital platform during the creation of the scenarios in the education application (END subsystem)

Fig. 3. An overview of the complete END scenario, containing points of interest and tasks for the visitor/user

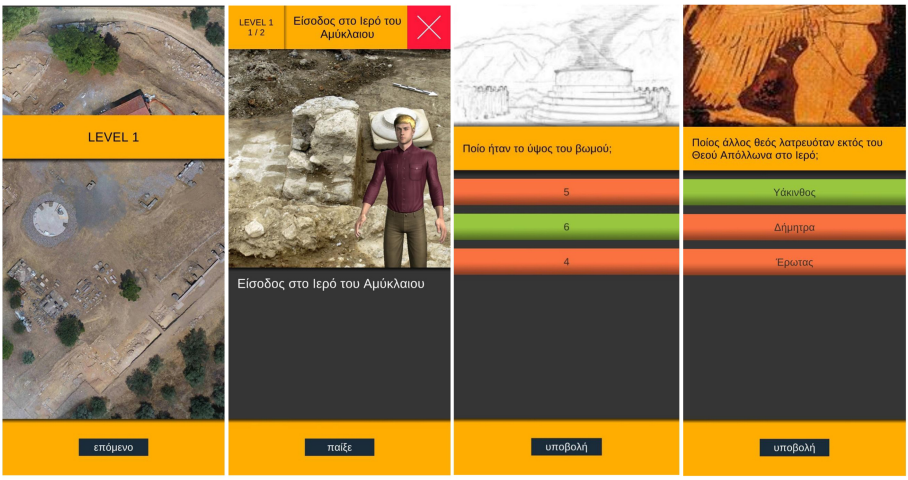

Fig. 4. The AR-App during the first scenario

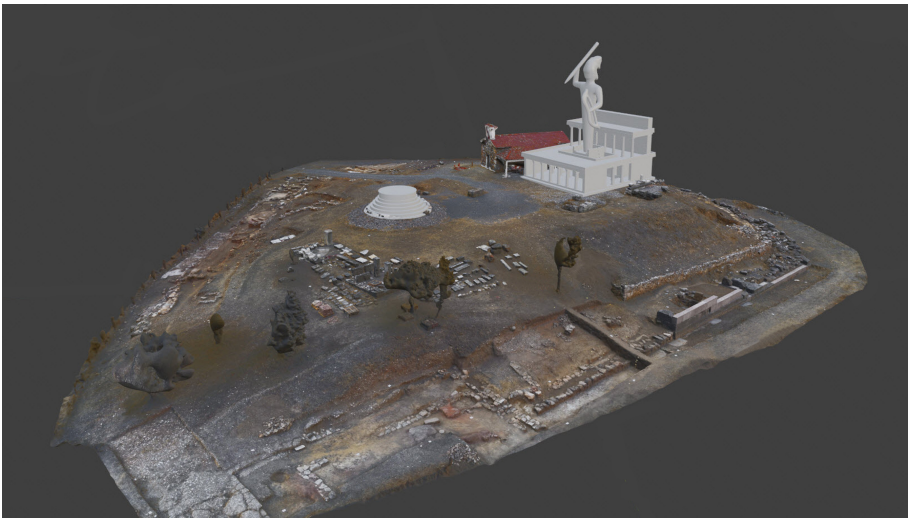

Fig. 5. Indicative 3D models (in progress) of monuments that will be used in augmentations in the relative scenarios

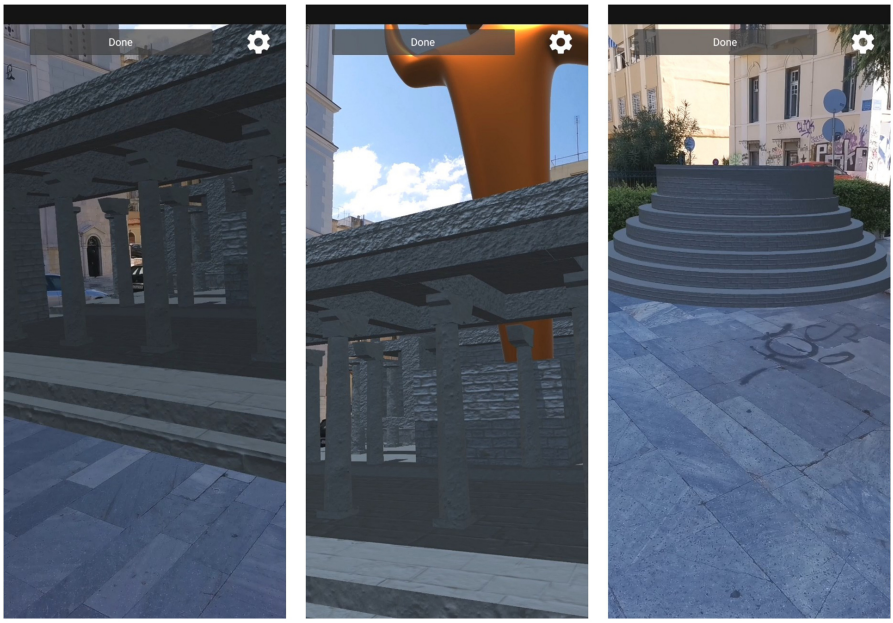

Fig. 6. AR-App augmentation lab tests

Next up, in the mixed reality subsystem a scenario was devised to show the methodology of an archaeologist and the progress of the excavation. The research team combined the above-mentioned theory, the excavation documentation, and the findings, the most important of which were digitized, with the 3D models of the strata in one of the excavation's trenches (Fig. 7) as the basis of the scenario. In the MRT subsystem one can create scenes for a scenario, where each scene contains a trench layer 3D model, and in turn for each scene create different findings groups (Fig. 8) where the appropriate objects are integrated from the CDP and visualized at their finding point accompanied with their documentation in the MR-App.

After the creation of the scenario in the MRT, the presenter sets in the archaeological site, with the use of MR-App in HoloLens 2, in placing mode, the position of the 3d excavation layers and its relative 3D objects (Fig. 9). The positions of the 3D holograms were saved in Azure Spatial Anchors so that the information can be used across multiple HoloLens, iOS, and Android devices. When the locations of all 3D holograms in the real world of the scenario are set up, the presenter uses the presenter mode of the MR-App. The MR-App recognizes the environment, and the first holograms of the scenario are appearing at their original placements (Fig. 10), so the presenter starts the interaction with them and gradually proceeds to the next steps of the presentation of the phases of the specific excavation scenario.

Fig. 7. An overview of the 3D models of excavation strata that are used in the MRT scenario

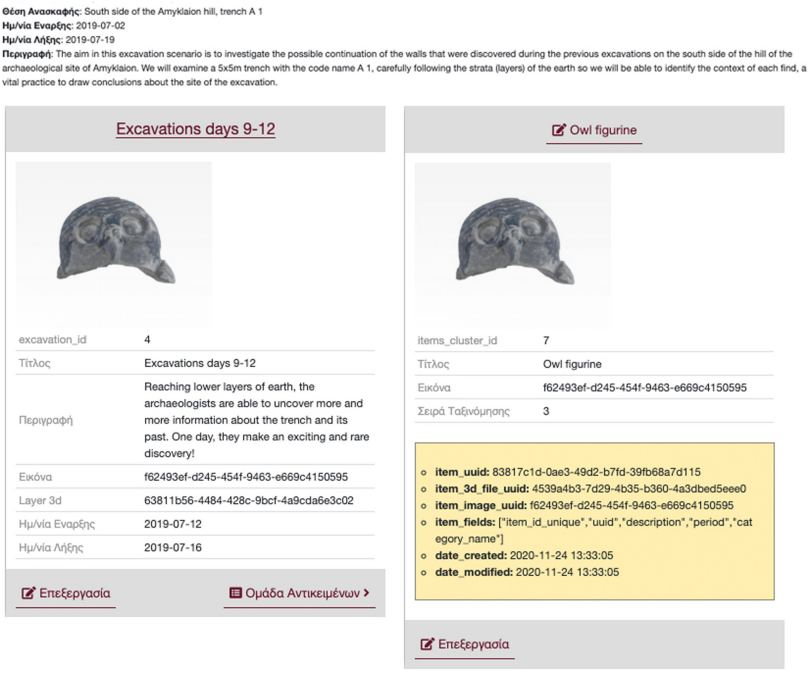

Fig. 8. The digital platform during the creation of the scenarios in the education application (MRT subsystem)

Fig. 9. HoloLens lab tests, placing mode

Fig. 10. HoloLens lab tests, presenter mode

That way, with the use of appropriate MR optical media, e.g., Microsoft HoloLens, the users can navigate a simulation of the real trench's excavation layer by layer, accompanied by the appropriate information to understand and experience the process and joy of discovery of the excavation. The AR-App and the MR-App will be thoroughly tested in the upcoming excavation season.

The elements of gaming [37] that are incorporated in the education application to engage visitors as players, relate to notions of progression, investment and the cascading information theory: with each subtask completed the users gather points and when they have amassed the needed number of points they level up and earn new badges. This adds an elementary incremental success and progression visualization. Achievements are awarded as a recognition for completing each scenario unit, which deepens the sense of pride for the work done in the application. Additionally, as new game scenarios can be easily created through the subsystems of the digital platform, a potentially infinite amount of them may be generated by the specialists, either easy and simple or more complex. In this aspect, the community will regularly receive new challenges and so will be inclined to check in periodically and thus cultivate feelings of investment and loyalty. Throughout the experience, the visitors navigate the learning environment, i.e., the archaeological site, to discover snippets of knowledge, a practice related to the cascading information theory which posits that information should be released gradually to gain the appropriate level of understanding at each point during a narrative. Special care has been taken not to overwhelm the visitors, so as not to distract them from the physical space, but instead to find new ways of connecting to it. Finally, it should be noted that the highlighted scenarios are only an example of the variety of narratives one can create in the platform subsystems utilizing different aspects of the platform's possibilities.

6 Conclusions and Future Work

The present case study proposed a design methodology of educational scenarios for digital platforms which utilize augmented and mixed reality elements based on the user needs and understanding of the environment, the topography and the narratives of the site. It is showcased in an innovative digital platform for the creation of educational applications for the archaeological site of the Amyklaion using augmented and mixed reality and gamification methods. While the aim of the platform is to revive ancient Amyklaion as a living museum, which visitors can enter and understand [38], it should be made clear that the restoration of the entire past of the archaeological site is impossible, despite all technological applications. Moreover, the composition and interpretation of the past is influenced by the ideological perceptions and experiences of the modern age [39]. Nevertheless, even with these unavoidable constraints in mind, the digital platform is a unique tool that will increase the ability to create easy and impressive results for original educational applications.

Further research of the output of the presented application, specifically on the design of the scenarios and serious games using an established assessment framework [40], and on the perception of it by its users, both creators and final users by way of quantitative and qualitative research methods, is in order. As the archaeological site is

undergoing excavations and is essentially unvisitable for long periods of time, the research and feedback loop for the survey and the scenarios will be completed in the coming excavation season. This would potentially contribute to the wider research on the theoretical foundation that can explain the positive effects of gamification and new technologies [41]. Additionally, the adaptation of the digital platform and its resulting education applications on other archaeological sites or cultural settings such as museums and open-air art exhibitions is seen as a necessary long-term addition to the project by the research team.

Acknowledgment. The current research is based on the project «Digital platform for the development of educational applications focused on cultural heritage tourism with the use of augmented reality, mixed reality and gamification» (ACRONYM: AMREP - Augmented - Mixed Reality Educational Platform), which is co-financed by the European Union and Greek national funds through the Operational Program Competitiveness, Entrepreneurship and Innovation, under the call RESEARCH – CREATE – INNOVATE.

References

1. Cassidy, B., et al.: A virtual reality platform for analyzing remote archaeological sites. In: Proceedings of the 32nd International BCS Human Computer Interaction Conference. BCS Learning & Development Ltd., Swindon (2018). https://doi.org/10.14236/ewic/HCI2018.171
2. Liritzis, I., et al.: Digital technologies and trends in cultural heritage. Mediterr. Archaeol. Archaeom. **15**(3), 313–332 (2015). https://doi.org/10.5281/zenodo.33832
3. Pollalis, C., et al.: HoloMuse: enhancing engangement with archaeological artifacts through gesture-based interaction with holograms. In: Proceedings of the Eleventh International Conference on Tangible, Embedded, and Embodied Interaction, pp. 565–570. ACM, New York (2017). https://doi.org/10.1145/3024969.3025094
4. Saborido, A.E., Castanò, F., Buono, M.: Review on new technologies in art and archaeology: the Vesuvian cities. In: IOP Conference Series: Materials Science and Engineering. Florence Heri-Tech – The Future of Heritage Science and Technologies, vol. 364 (2018). https://doi.org/10.1088/1757-899X/364/1/012051
5. Papagiannakis, G., et al.: Mixed reality, gamified presence and storytelling for virtual museums. In: Lee, N. (ed.) Encyclopedia of Computer Graphics and Games. Springer, Cham (2018). https://doi.org/10.1007/978-3-319-08234-9_249-1
6. Petrelli, D.: Making virtual reconstructions part of the visit: an exploratory study. DAACH **15**, e00123 (2019). https://doi.org/10.1016/j.daach.2019.e00123
7. Arya, A., et al.: Collaborating through space and time in educational virtual environments: 3 case studies. J. Interact. Technol. Pedagogy **2** (2012). https://jitp.commons.gc.cuny.edu/collaborating-through-space-and-time-in-educational-virtual-environments-3-case-studies/
8. Deterding, S., et al.: From game design elements to gamefulness: defining gamification. In: Proceedings of the 15th International Academic MindTrek Conference: Envisioning Future Media Environments, pp. 9–15. ACM, New York (2011). https://doi.org/10.1145/2181037.2181040
9. Kapp, K.M.: The Gamification of Learning and Instruction: Game-Based Methods and Strategies for Training and Education. Pfeiffer, San Francisco (2012)
10. Zichermann, G., Linder, J.: The Gamification Revolution. McGraw-Hill Education, New York (2013)

11. Nacke, L.E., Deterding, S.: The maturing of gamification research. Comput. Hum. Behav. **71**, 450–454 (2017). https://doi.org/10.1016/j.chb.2016.11.062
12. Chapman, J., Rich, P.: The design, development and evaluation of a gamification platform for business education. In: Academy of Management Annual Meeting Proceedings, vol. 2015, no. 1 (2017). https://doi.org/10.5465/AMBPP.2015.185
13. Dougherty, J., Nawrotzki, K. (eds.): Writing History in the Digital Age. University of Michigan Press, Ann Arbor (2013). https://doi.org/10.3998/dh.12230987.0001.001
14. Shilkrot, R., Montfort, N., Maes, P.: nARratives of augmented worlds. In: Proceedings of the IEEE International Symposium on Mixed and Augmented Reality - Media, Arts, Social Science, Humanities and Design. IEEE, Munich (2014). https://doi.org/10.1109/ISMAR-AMH.2014.6935436
15. Viana, B.S., Nakamura, R.: Immersive interactive narratives in augmented reality games. In: Marcus, A. (ed.) DUXU 2014. LNCS, vol. 8518, pp. 773–781. Springer, Cham (2014). https://doi.org/10.1007/978-3-319-07626-3_73
16. Yovcheva, Z., et al.: Empirical evaluation of smartphone augmented reality browsers in an urban tourism destination context. IJMHCI **6**(2), 10–31 (2014). https://doi.org/10.4018/ijmhci.2014040102
17. Hammady, R., Ma, M., Temple, N.: augmented reality and gamification in heritage museums. In: Marsh, T., Ma, M., Oliveira, M.F., Baalsrud Hauge, J., Göbel, S. (eds.) JCSG 2016. LNCS, vol. 9894, pp. 181–187. Springer, Cham (2016). https://doi.org/10.1007/978-3-319-45841-0_17
18. Kotsopoulos, K., et al.: An authoring platform for developing smart apps which elevate cultural heritage experiences: a system dynamics approach in gamification. J. Ambient Intell. Human. Comput. (2019). https://doi.org/10.1007/s12652-019-01505-w
19. Bacca, J., et al.: Mobile augmented reality in vocational education and training. Procedia Comput. Sci. **75**, 49–58 (2015). https://doi.org/10.1016/j.procs.2015.12.203
20. Dunleavy, M., Dede, C.: Augmented reality teaching and learning. In: Spector, J.M., Merrill, M.D., Elen, J., Bishop, M.J. (eds.) Handbook of Research on Educational Communications and Technology, pp. 735–745. Springer, New York (2014). https://doi.org/10.1007/978-1-4614-3185-5_59
21. Ellenberger, K.: Virtual and augmented reality in public archaeology teaching. Adv. Archaeol. Pract. **5**(3), 305–309 (2017). https://doi.org/10.1017/aap.2017.20
22. Huang, T.C.: Seeing creativity in an augmented experiential learning environment. Univ. Access Inf. Soc. **18**, 301–313 (2019). https://doi.org/10.1007/s10209-017-0592-2
23. Matsuo, M.: A framework for facilitating experiential learning. HRDR **14**(4), 442–461 (2015). https://doi.org/10.1177/1534484315598087
24. Rousou, M., et al.: Engaging visitors of archaeological sites through "emotive" storytelling experiences: a pilot at the Athenian Agora of Athens. Archeologia e Calcolatori **28**(2), 405–420 (2017). https://doi.org/10.19282/AC.28.2.2017.33
25. Mott, B.W.: Decision-theoretic narrative planning for guided exploratory learning environments. Dissertation, North Carolina State University (2006)
26. Riedl, M., Saretto, C.J., Young, R.M.: Managing interaction between users and agents in a multi-agent storytelling environment. In: Proceedings of the Second International Joint Conference on Autonomous Agents and Multiagent Systems, pp. 741–748. ACM, New York (2004). https://doi.org/10.1145/860575.860694
27. Caracelli, V.J., Greene, J.C.: Crafting mixed-method evaluation designs. New Dir. Eval. 19–32 (1997). https://doi.org/10.1002/ev.1069
28. Greene, J.C.: Mixed Methods in Social Inquiry. Jossey-Bass, San Francisco (2007)
29. Bruner, J.S.: The act of discovery. Harv. Educ. Rev. **31**, 21–32 (1961)
30. Papert, S., Harel, I.: Constructionism. Ablex Publishing, Norwood (1991)

31. Winn, W.D.: A conceptual basis for educational applications of virtual reality. HITL technical report R-93-9, Human Interface Technology Laboratory, Seattle, WA (1993)
32. Vlizos, S.: Das Heiligtum und seine Beigaben: Bronzestatuetten vom Amyklaion. In: Frielinghaus, H., Stroszeck, J. (eds.) Kulte und Heiligtümer in Griechenland: Neue Funde und Forschungen. Beiträge zur Archäologie Griechenlands, Mainz, vol. 4, pp. 71–95 (2017)
33. Vlizos, S.: Metallwerkstätten, Produktion und Infrastruktur des Heiligtums: der Fall des spartanischen Amyklaions. In: Lo Monaco, A. (ed.) Spending on the Gods. Economy, Financial Resources and Management in the Sanctuaries in Greece. Annuario della Scuola Archeologica di Atene e delle Missioni Italiane in Oriente, Supplementum, Athens, vol. 7, pp 37–46 (2020)
34. Amykles Research Project (n.d) Testimonia. https://amyklaion.gr/en/sanctuary/testimonia. Accessed 29 Nov 2020
35. Amykles Research Project (n.d). https://amyklaion.gr/en. Accessed 29 Nov 2020
36. Delivorrias, A., Vlizos, S. (eds): Amykles Research Project: Works 2005–2010, vol. 11–12, pp. 73–191. Benaki Museum (2012)
37. Salen, K., Zimmerman, E.: Rules of Play: Game Design Fundamentals. The MIT Press, Cambridge (2003)
38. Jacobsen, J., Holden, L.: Virtual heritage: living in the past. Techné **10**(3), 55–61 (2007)
39. Champion, E.: Heritage role playing: history as an interactive digital game. In: Pisan, Y. (ed.) Proceedings of IE 2004: Australian Workshop on Interactive Entertainment. University of Technology, Sydney (2004)
40. Mitgutsch, K., Alvarado, N.: Purposeful by design? A serious game design assessment framework. In: Proceedings of the International Conference on the Foundations of Digital Games, pp. 121–128. ACM, New York (2012). https://doi.org/10.1145/2282338.2282364
41. Sailer, M., et al.: How gamification motivates: an experimental study of the effects of specific game design elements on psychological need satisfaction. Comput. Hum. Behav. **69**, 371–380 (2017). https://doi.org/10.1016/j.chb.2016.12.033