

Article

Dive in the Past: A Serious Game to Promote the Underwater Cultural Heritage of the Mediterranean Sea

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Abstract: In the last decades, the popularity of video games has been increasing thanks to their unique ability to engage their audience and create empathy. Among them, serious games have additional purposes besides entertainment, such as learning and behaviour change. Serious games, in fact, have been successfully applied to different fields, including education, health, tourism, and cultural heritage. In this context, the paper describes a novel serious game developed for increasing awareness and promoting the Underwater Cultural Heritage (UCH). In particular, the paper focuses on the *Dive in the Past* Serious Game which allows users to simulate a virtual dive into the Mediterranean Sea to explore accurate and life-sized 3D reconstructions of underwater archaeological sites. The purpose of the game is twofold: to engage diver and non-diver tourists into a virtual interactive exploration of underwater sites through digital storytelling and challenges; to increase awareness and knowledge on Mediterranean UCH. This work has been carried out in the context of the MeDryDive project, an EU co-funded under the COSME Programme, which aims to create personalized dry dive experiences for the promotion of Mediterranean UCH sites as distinctive tourism destinations.

Keywords: serious game; underwater archaeology; 3D reconstruction; Underwater Cultural Heritage; Mediterranean Sea



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1. Introduction

By definition, a Serious Game (SG) is a game with a purpose, that is a software belonging to the videogame's category which is used to accomplish a non-gaming-related objective, through the distinguishing features of the gaming medium. A SG's purpose is to infuse instruction into the game play experience. Play is a primary socialization and learning mechanism common to all human cultures [1] and an ever-increasing large and growing population is familiar with playing games. Furthermore, SGs can present users with realistic and compelling challenges, highly stimulating their information processing capabilities and capturing their concentration span for long durations [2,3]. Furthermore, intrinsic motivations, such as enjoyment or fun, produce deeper engagement and higher persistence in learning activities [4]. This would explain the successful adoption of video games for educational purposes in several domains such as education, training, and the cultural heritage field [5–9]. A burgeoning number of studies demonstrate that video gaming can have strong positive effects on visual processing of spatial characteristics of information, attentional processing, executive functioning, inductive reasoning, mental rotation, memory, and task motivation [10–18]. The main pedagogical element that stands out is that users experience the game in a direct, unmediated way [19–22]. By simply playing the game, the user can acquire the dynamics of the game, its basic concepts and

the entire body of knowledge needed to progress deeply in the game and experience more advanced features [23]. This is a fundamental psycho-pedagogical element of game-based learning, which in turn leverages the concept of intrinsic motivation to achieve and win within the game [24–26] and seamlessly implements an example of experiential learning or learning-by-doing; that is, learning by doing and being active in the learning process. This is mainly due to the engagement, in terms of cognitive involvement, generated by the entertainment value of video games that acts as a motivator for players to learn while having fun [27]. Engagement is in fact a key predictor of success in any educational or training programme [28–31]. In addition to the engagement, the emotional involvement is a necessary component of a serious game that promotes and maintains the player's motivation [32–36]. Emotion captures attention, improves memory, and helps build tension and excitement to keep the player enticed to play. However, it is not just the playing of the game that needs to be emotionally engaging. The storyline featured in the game should be entertaining, enabling the player to self-identify and empathize with the characters [27]. There are many examples of SGs for cultural heritage [37–42] that use game technology to create entertaining and cultural learning experiences. Both these characteristics can coexist without conflicting because the entertainment factor encourages the public to participate, but their understanding of what they have learnt persists beyond the experience [43]. The importance of these digital learning tools based on playful activities is more evident when they let players closely examine an environment without the barriers of time and space. SGs, in fact, allow players to simulate real-life situations that could be otherwise inaccessible to them [44], as is the case of the Underwater Cultural Heritage (UCH) [45–48]. UCH is, in fact, an immeasurable historical and archaeological resource, with extensive and varied assets (sunken cities, ancient shipwrecks, prehistoric submerged landscapes, sacrificial sites, and remains of ancient fishing installations and ports) that cannot be easily accessed due to a number of limitations imposed by the underwater environment or by local and national legislative frameworks. SGs can be a very useful and effective tool to spread and increase awareness and knowledge about underwater archaeological sites and, furthermore, to make them virtually accessible to the general public without the constraints of distance or time [49–51]. These potentialities are also consistent with the rules defined by the United Nations Educational, Scientific and Cultural Organization (UNESCO) in the 2001 general conference on the Protection of the Underwater Cultural Heritage [52,53]. In particular, the States Parties have ratified that the protection of Underwater Cultural Heritage through in situ preservation shall be considered as the first option (Rule 1); public access to in situ Underwater Cultural Heritage shall be promoted, except where such access is incompatible with protection and management (Rule 7); information and data gathered during research activities carried out in the underwater archaeological sites shall be disseminated for public education and popular presentation (Rules 35 and 36) [52]. The application of SGs in the UCH field also contributes to the Blue Growth strategy [54], set by the European Union, which aims to support cooperation among museums, research institutes, and tourism companies for the development of innovative and sustainable solutions and products, with an extensive use of information and digital technologies that respond to visitors' expectations [55].

This paper presents a novel serious game developed for increasing awareness and promoting of UCH. Differently from the works present in the literature in which partial reconstructions of the underwater sites or real finds set in fictional scenarios are provided, this game offers a faithful and complete reconstruction of submerged archaeological sites, including the remains, the finds and the surrounding area. In particular, the *Dive in the Past* (in Supplementary Materials) serious game allows users to simulate a virtual dive into the Mediterranean Sea to explore accurate and life-sized 3D reconstructions of four underwater archaeological sites. This research has been carried out in the context of the MeDryDive project (<https://medrydive.eu> accessed on 14 October 2021) co-financed under the COSME programme of the European Union. The project involves seven partners from five European countries: Italy, Greece, Croatia, Montenegro, and Albania. This partnership aims to

design and develop innovative transnational thematic tourism products, with a focus on Mediterranean UCH assets, offering diving and non-diving activities and integrating personalized cultural and creative applications. For its initial phase, MeDryDive focuses on four underwater pilot sites: the Underwater Archaeological Park of Baiae (Naples, Italy); the Peristera shipwreck (Peristera island, Greece); the Gnalić shipwreck (Biograd Na Moru, Croatia); and the Oreste shipwreck (Trsteno Bay, Montenegro).

2. Underwater Archaeological Sites

The four pilot sites listed above were selected on the basis of objective criteria in order to meet the needs of the project and, in particular, the possibility to perform an accurate 3D reconstruction of the site in which to set the serious game. In particular, the pilot sites were selected on the basis of eleven criteria, seven essential and four complementary. The first ones refer to specific requirements (e.g., accessibility based on national legislative framework [52]; physical accessibility to the site) that the site must possess in order to be taken into consideration for selection procedures. The second ones aimed at valuing complementary features (e.g., attractiveness of the site; stakeholders' engagement) of the selected sites through a scoring system based on a scale from 1, least desirable, to 5, most desirable.

2.1. Underwater Archaeological Park of Baiae

The Underwater Archaeological Park of Baiae is located in the volcanic area of the Phlegrean Fields, a few kilometres north of Naples (Italy), and since 2002 has been declared a Marine Protected Area. This site is a typical representative of the phenomenon of bradyseism as the remains of the Roman age are actually at a depth ranging from 0 m to 15 m from the sea level, and only a few ruins are still on the coastline, inland. The submerged site can be easily visited by professional and recreational divers. The Underwater Park of Baiae (Figure 1) is famous also for its extensive submerged area of 177 hectares and the wide range of different architectural structures, i.e., fisheries and harbour buildings, thermal baths, residential buildings, and villas, with some decorations that are still preserved. The areas of concern for the MeDryDive project were the complex of the "Villa con ingresso a protiro-Villa with Vestibule" [56], dated to the first half of the II century AD, and the Sunken Nymphaeum of Claudius. The "Villa con ingresso a protiro" was restored for the first time in 2003 thanks to the "Restoring Underwater" Project that led to the restoration of a room with a white mosaic floor measuring around 4.5 m long and 2.5 m wide [57]. In 2010 a thermal room (caldarium) was restored under the direction of Roberto Petriaggi. In 2012 another campaign of 3D documentation [58] and conservation was executed under the direction of Barbara Davidde Petriaggi, with the restoration of some sectors of the archaeological complex and a room with a black and white mosaic floor. The Sunken Nymphaeum of Emperor Claudius is a rectangular-shaped building located at Punta Epitaffio. It has four niches on each of the longer sides and a semicircular apse on the short sides. Each niche hosts a statue representing the dynastic portraits of the "gens" Giulio-Claudia.

2.2. Underwater Archaeological Site of Peristera

The underwater archaeological site of Peristera (Figure 2) is located within the limits of the National Marine Park of Alonissos Northern Sporades (Greece), 1.5 miles to the east of the coast of Alonissos Island, around 150 m off the shore of Peristera island. A shipwreck was discovered in 1985 lying on a partly sandy and rocky sloping seabed at a depth ranging from 22 to 28 m. The wreck is formed by a thick concentration of amphorae tightly arranged that seem intact and relatively undisturbed, especially in the lower layers. The wooden hull has not been preserved and the few finds, such as a lead part of an anchor, cannot provide detailed information on the hull construction. Based on the finds, the Peristera shipwreck is one of the largest known shipwrecks of classical antiquity. According to the original survey team, it was probably an Athenian merchant vessel. The ship was at least 25 m

in length and 10 m wide based on the distribution of the amphorae found on the seabed. This was based on the finds of the systematic excavation that was conducted during the years 1992, 1993, 1999, and 2000–2001 by the Ephorate of Underwater Antiquities [59]. The ancient shipwreck of Peristera is the first UCH site in Greece to be open to the public in August 2020.



Figure 1. Underwater archaeological park of Baiae (image courtesy of Parco Archeologico dei Campi Flegrei and Centro Sub Campi Flegrei).



Figure 2. Underwater archaeological site of Peristera (Image courtesy of: the Greek Ministry of Culture and Sports, Ephorate of Underwater Antiquities).

2.3. The Gnalić Shipwreck

This shipwreck (Figure 3) is located near the small island of Gnalić, three nautical miles distant from the coastal town of Biograd na Moru in Central Dalmatia (Croatia). It lies on the seafloor at a depth of 23–27 m. It was officially recorded in 1967, and it is one of the most significant post-medieval shipwreck sites in the Mediterranean. Besides the wide range of interesting finds belonging to the ship's equipment and cargo, recent archival research has yielded hundreds of documents revealing the history of the ship and its rich political, economic, cultural, and historical context. In fact, the shipwreck remains

corresponded to those of *Gagliana* (Gaiana, or Gagliana), a merchantman with a capacity of 1200 Venetian barrels (Ven. botti), i.e., around 700 tons, and an estimated length of 35–40 m. It was built in Venice in 1569 for Benedetto da Lezze, Lazzaro Mocenigo, and Piero Basadonna. Captured by the famous Ottoman corsair Uluç Ali in 1571 and sold to Odoardo da Gagliano in Pera (Constantinople) in 1581, the ship sunk at Gnalić in early November 1583, loaded with precious cargo shipped from Venice to Constantinople. The artefacts from the shipwreck include weapons, the ship's equipment and cargo, and a variety of organic material packaging. Three rescue campaigns were conducted in 1967 and 1968 [60], with an additional two campaigns in 1972 and 1973 [61]. Finally, a partial excavation of the shipwreck took place in 2012, providing a unique opportunity to verify the remaining archaeological potential of the site, which proved decisively high [62]. A systematic program of investigation began in 2013, and through October 2017 has encompassed approximately 200 square m of ship remains and seabed. At the moment, access to this protected underwater heritage is provided to the public through licensed diving centres.



Figure 3. The Gnalić shipwreck (Image courtesy of: University of Zadar–Adrias Project).

2.4. The Oreste Shipwreck

The *Oreste* shipwreck (Figure 4) is located 2.5 km away from the town of Budva (Montenegro). The original name of the ship was *Moorby*. It was built by Ropner & Sons, at Stockton-on-Tees (England), in 1896, and was renamed in 1926 by the new owner Mateo Scuderi, of Catania [63]. *Oreste* has long been known to local fishermen and divers as a nameless wreck. The ship is mentioned for the first time in the book “Lost Commercial Ships-Italian Navy-in World War II” and again in the book “Lloyd’s Register of Ships”, which had the number of the ship in its contents [64]. On 27 March 1942, while on its way from Split to Bari, at about 10 o’clock, *Oreste* landed in a mine and sank within two hours. The ship sank to the flat sandy seabed at a depth of 32 m. During the explosion, the ship broke into two parts which landed on the seabed about 20 m apart. On the stern are the stern tubes. Steam loading winches, in almost intact condition, are arranged across the deck. Remains of the steam engine protrude from the deck of the ship. On the scattered parts of the command bridge, one can clearly see parts of the steering gear characteristic of ships of that era. There are no known artefacts from the shipwreck held in the museums in Montenegro. Unofficial sources claim that since the time of its sinking, the wreck has been victim of looting and vandalism by locals, who have been removing ship installations and parts of the structure.



Figure 4. The *Oreste* shipwreck (Image courtesy of: BUDVA Diving).

3. Materials and Methods

As mentioned in Section 1, the *Dive in the Past* serious game aims to raise awareness and promote the UCH of the Mediterranean Sea. Its target audience is composed both of people who already have knowledge about the UCH and people who have little understanding of it. In particular, the game will target divers and non-divers globally, and it is suitable for all age groups, starting with elementary school children. To fulfil this purpose, the game has been designed to be fun and challenging for the players by including 3D environments and engaging storytelling. In particular, the requirements for the development activities have been defined on the basis of the following user needs: playing with smartphones and tablets; playing the game without an internet connection; getting involved in the story; obtaining information about the underwater environment and diving activities; exploring the virtual replica of the actual underwater sites obtaining historical and geographical information about them; and simulating a diving session. In order to meet these needs, the design and development activities have been structured in the following stages: 3D reconstruction of the underwater archaeological sites, pre-production, game design, and storytelling. All the activities, from the concept to the development and testing stages, have been carried out with the direct involvement and support of archaeologists, restorers, and experts from UCH. Such support has been essential both in the realization phase of the 3D models, in order to assure a correct and accurate representation of the sites and of the finds, and in the preparation phase of the dialogues and of the textual information contained in the game.

3.1. 3D Reconstruction

The activities undertaken underwater, within the submerged archaeological sites, have demanded considerable effort because of the presence of sea currents, dimensions of the site, and different conditions of brightness and turbidity. For these reasons, the 3D reconstruction of the underwater archaeological sites has been a long and articulated process that consists of the following five steps. The first step is to inspect the underwater site and aims to identify depth and locations of the archaeological remains and the extension of the area. The second step deals with the acquisition of the optical data which, according to the specific needs of the underwater site, can be performed with the integration of acoustic acquisition techniques [51,65] and carried out by scuba divers or by underwater Remotely Operated Vehicles (ROVs) or Autonomous Underwater Vehicles (AUVs). The optical survey has been carried out according to standard photogrammetric techniques. In particular, the camera has been set up in a downward-looking position and moved horizontally, right-left and left-right, on overlapping strips along straight lines by ensuring a 70–80% forward overlap and 50% side overlap. Furthermore, oblique poses of the camera have been used for the occluded areas, not visible in the downward-looking position. The third step is the selection and preparation of the acquired data. In particular,

the optical data has been improved through image enhancement techniques. In fact, due to the attenuation that light undergoes in its propagation in water, underwater images are generally affected by low contrast, uneven lighting, blurring, attenuation of colours and noise. These issues, which inevitably impact the quality of the results, can be minimized by employing dedicated algorithms and software tools [66]. In the following step, a structure-from-motion (SfM) 3D reconstruction has been performed, using commercial software, and a local metric coordinate system based on a network of Ground Control Points (GCPs) has been adopted to scale and reference the sparse 3D point cloud. Then, a Multi-View Stereo (MVS) algorithm has been used to produce a dense 3D point cloud that is further processed to obtain a polygonal mesh. In the last step, techniques based on the projection and blending of 2D images on the 3D surface have been adopted for mapping the texture on the 3D model. The following figure depicts the textured 3D reconstruction of, respectively, the Nymphaeum of Baiae (Figure 5a), Peristera site (Figure 5b), Gnalić shipwreck (Figure 5c), and *Oreste* shipwreck (Figure 5d).

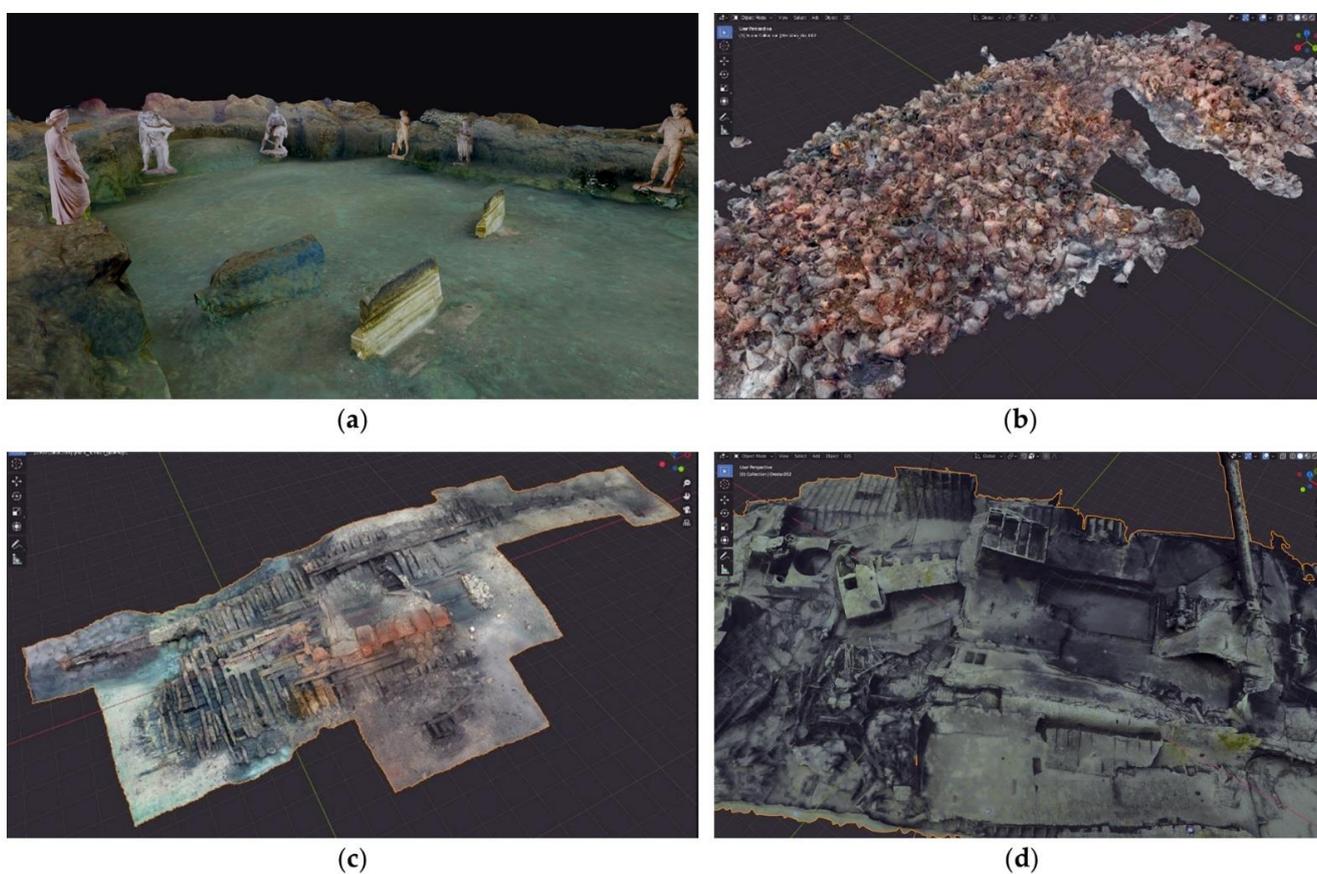


Figure 5. 3D reconstruction of the Nymphaeum of Baiae (a); Peristera site (b); Gnalić shipwreck (c); and *Oreste* shipwreck (d).

3.2. Pre-Production

The pre-production starts with the definition not only of the domain constraints but also of hardware limitations and input data handling, which are taken as guidelines for the design of the serious game. The selection of pilot sites leads to the first factor to be taken into account, which is the chronological coherence of the game. Since the archaeological sites have different dates, the narrative element gains a fundamental role in the game because it guides the player in the exploration of the various underwater archaeological sites and in the discovery of the different historical ages to which they belong. The game narrative, on one side, helps keep people engaged and, on the second side, allows to introduce and reinforce the scientific value and enhance the educational purpose of the game [67,68].

In order to create a compelling experience for the user, key features have been identified from both the traditional gaming mechanics and key features [69] and an established framework for the Serious Game model for cultural heritage [40] based on the Sandbox Serious Games concept [70]. In particular, since the app is focused on knowledge acquisition, the main focus has been on creating a proper cognitive-supporting structure. While the knowledge is distributed in the virtual world of the game (thus satisfying the need for a concrete spatial organization), the game features simple activities (embodying units of knowledge) that can be completed by the player (minigames), which help to construct meaning and build lasting memories while deepening understanding [71].

In particular, the MeDryDive's game concept has focused on the following game elements: self-representation with Avatars, three-dimensional environments, narrative context, feedback, and time pressure. Once the game elements have been defined, then the development process has focused on the implementation of various fast-prototype concepts, which has helped to define the final look of the game, both in terms of game system (first-person or third-person view) and mechanics (items collection, puzzle-solving and so on). At first, it was decided to adopt a third-person view during visualization, with the player controlling an underwater drone for exploring the different archaeological underwater sites. This solution provides the player with a strong arcade feeling, since the character's movement is controlled by two touchscreen joysticks. Nevertheless, the final choice was to implement of a first-person view (Figure 6) which improves player immersivity and enhances exploration of virtual scenarios. Some experts suggest the first-person visualization as it has the advantage of creating a more emotional state and feelings in the users' mind. Oftentimes, the first-person visualization works better in terms of creating the emotions and feelings through the player's eyes. This is because players imagine themselves doing the things.



Figure 6. First-person perspective visualization of the *Dive in the Past* game.

One of the biggest growth areas of gaming has been in the area of mobile gaming [72]. Smartphones and tablets, in fact, have become pervasive as evidenced by their use almost anywhere, e.g., public transport, restaurants, etc. [73]. As a consequence, in order to meet user needs and to encourage the widest possible diffusion of the *Dive in the Past* serious game, this has been developed for both Android and iOS platforms which allow users to play the game on smartphone and tablet devices. Furthermore, the game is also available for the most recent virtual reality technologies, e.g., Oculus Quest, to increase the degree of immersion within the virtual scenarios.

3.3. Game Design

The outcomes of the pre-production stage have been adopted as input for the concept design of the game. The aim was to merge a realistic underwater exploration not only with an appropriate gaming challenge but also with an engaging narrative feature. *Dive in the Past* has been then conceived as a first-person adventure game that takes place in the four different underwater archaeological sites, where players have to explore the realistic 3D reconstruction of the submerged environments to accomplish a sort of treasure hunt. The game features four levels, each one is dedicated to an underwater site, and the temporal sequence of the game follows the reverse chronological order of the dating of the sites. Consequently, the first level of the game is set in the *Oreste's* underwater site, the second level in the Gnalić's site, the third level in the underwater archaeological park of Baiae, and the last level in the underwater archaeological site of Peristera. When the player starts the first level, he/she is assigned a series of tasks that consists in hunting items located within the submerged site. Once all tasks are accomplished, the player unlocks a new storytelling session and gains the access to the next level, hence the possibility to explore a new site. In particular, each level consists of two different game phases. The first phase is set in the 3D underwater scenario where the user is invited to explore the submerged archaeological site to accomplish the assigned tasks. When all tasks are accomplished, the player enters the second phase, characterized by a two-dimensional environment, which focuses on narrative aspects that provide the information to move to the next level. In this two-dimensional environment, the player is invited to solve three minigames, which are specific to each level, whose purpose is to reinforce the educational aspect of the game by providing historical and archaeological information about the explored site.

3.4. Storytelling

As stated before, the narrative feature is a key element in *Dive in the Past* serious game. In fact, its narrative identity allows to merge exploration and minigames, tridimensional environments and animated videos, since everything is coherent with the overall narration. Given the great importance of this feature, the writing of every script and dialogue and the production of 2D graphics were assigned to external specialists and professional artists.

The storytelling consists of a journey through the centuries but set in modern days, where a young scientist named Albert, i.e., the player's alter ego, finds an ancient diary which keeps a great secret. Inside its pages, there is partial information about the four sites and four precious items, and he decides to visit them and start exploring, to recover these items using his technologic gears (high-tech scuba diving masks and scanners). Each item unlocks a portion of the story of the previous owner of the diary, a damned soul, who reincarnates every time he dies, trying to atone his sins but systematically failing. Hence, the main character has to help this soul, trying to understand which is the very first sin he made, and making it free.

The storyline sequence of the game, depicted in Figure 7, consists of a single narrative flow, beginning with the finding of the diary and ending with the discovery of the truth, that runs on two different temporal levels: the present and the past. The main character has to explore the four sites backwards in time, starting from the latest, *Oreste*, and then to Gnalić, Baiae, and finally Peristera, because every site unveils the story of a different reincarnation of the soul. Each level alternates the exploration of the related underwater site, set in present days, with the story of the reincarnation, set during the past. These past stories can be considered as four sub-plots, with each reincarnation as the main protagonist, and they are the Radio Man (working on the *Oreste* ship), the Alchemist (shipwrecked at Gnalić), the Cook (working for the Emperor in Baiae), and the Slave (working but shipwrecked in Peristera). These tales are connected by some narrative elements aimed to underline the strong relationship existing between their characters, despite their temporal distance and social differences. Indeed, all of them die cruelly after having committed a terrible mistake: to put their vested interest before moral cleanness. This way, the Radio Man pretends to sacrifice his life for his fellows' salvation, while he's actually working for the enemy; the

Cook pretends to make a gift to the Emperor when, instead, he's trying to kill him; the Alchemist is just a thief but uses his persuasive abilities and magical knowledge to let the others think he's an influential man; the Slave cheats his owner to gain the freedom and, most of all, commits perjury against Zeus. Even if the Slave's story is the last one in the game structure, it is actually the trigger event: he challenges the Gods' power and Zeus punishes him, cursing his soul forever. The storytelling key is that the Dive in the Past's characters are not victims of the diary but of their selfishness. Furthermore, there are two special scenes: the Tutorial Scene that is a demo environment that allows the player to practice with the game controls and the Epilogue Scene that concludes the narrative setting and happens only on the Diary pages.

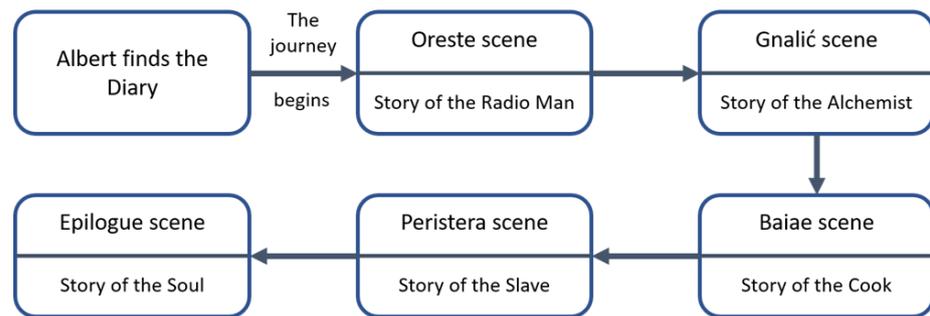


Figure 7. *Dive in the Past* storyline sequence.

4. Results

Dive in the Past had a period of pre-launch, starting on the 26 February 2021, then it officially was launched worldwide on the 21 March 2021. It is available free of charge in the Google Play (Android mobile operating systems) [74] and Apple (iOS mobile operating systems) [75] stores (Figure 8a). In the first four months since its official launch date, the game has received three major updates, the current version is 1.1.2, and it has been downloaded by more than 35,000 players.

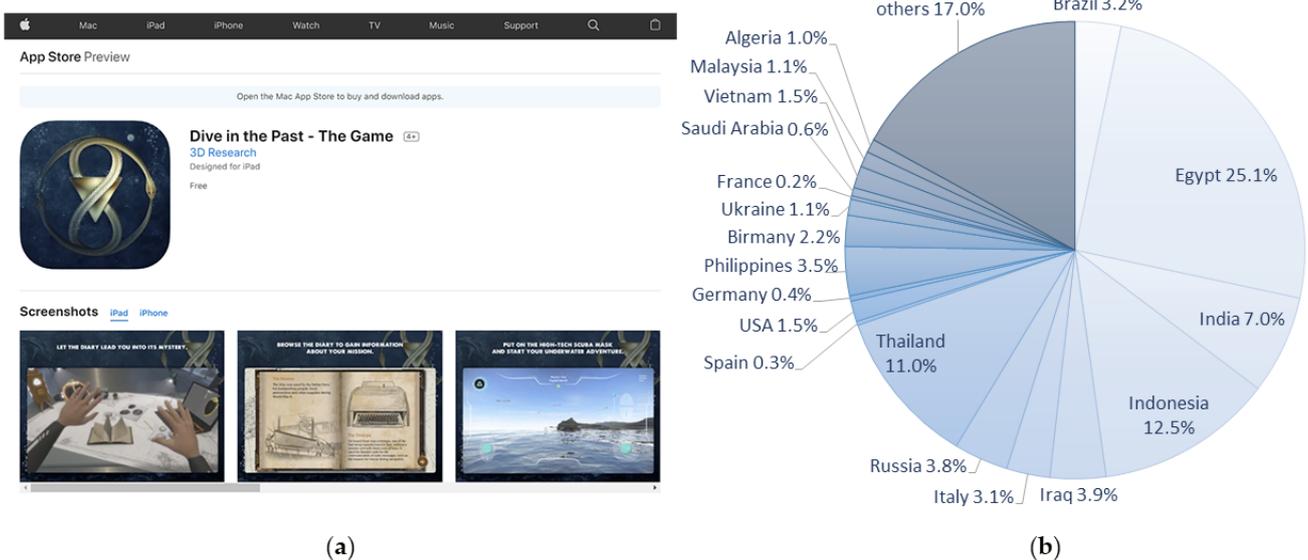


Figure 8. Apple store page for the download of the *Dive in the Past* serious game (a) and app downloads by geographical area (b).

Subsequent to the date of publication, the game has had an immediate response from the public in terms of downloads whose geographical area of origin is not limited to that

of the four underwater archaeological sites but concerns a wide diffusion at international level (Figure 8b).

Data incoming from the Google Play Console after the game's launch have been analysed. Users' sentiment towards apps can in fact be assessed by analysing their review comments and ratings [76]. User-review can be identified as an informal piece of text without a predefined structure [77], and they are associated with star ratings on Google Play, that is, a user can rate an app assigning it a number of stars from 1 to 5. In particular, the overall average rating of the *Dive in the Past* serious game (taking into account both ratings with review and ratings without review) is currently 4.2/5 stars. In order to conduct the analysis, a multi-step process has been used that addresses two tasks: the identification of topics and the extraction of opinions associated with these features [76]. Before the analysis, data has been pre-processed in order to remove all inconsistent feedback which could introduce noise thus leading to inexact findings [78]. Inconsistent feedback is identifiable by a discrepancy between the assigned number of stars and text content [77]. Of a total of 242 ratings with a review, 16 have been removed from the analysis. The relevant keywords [76] identified in the text comments, tied with the corresponding rating, lead to the results shown in Figure 9. In particular, Figure 9a shows the percentage of the most recurrent keywords, while Figure 9b shows the average rating per keyword. What emerges from the data analysis is that the most recurrent words in written reviews are "Concept" and "Gameplay", which recurs respectively in the 48.3% and 27.0% of reviews indexed. They have an associated average value of 4.8/5 stars ("Concept") and 5/5 stars (Gameplay). This means users appreciate the game mechanics adopted in the app, which is composed of a 3D exploration part and a puzzle mini-game section as explained in Section 3. The word "Lag" recurs in 21.3% of indexed reviews, with an associated rating of 2.9/5. This word can be associated with framerate drops or overall low framerate experiences. Framerate depends on hardware capabilities and software optimization [79]. "Graphics" is another keyword for this analysis, featured in 13.5% of indexed reviews. The rating associated with it is 4.8/5. The keyword "Ads" recurs in 11.2% of indexed reviews with an associated rating of 4.0/5. In conclusion, results show how users tend to appreciate the game's mechanics (Gameplay and Concept keywords) and visual quality (Graphics keyword), while performance stability over the wide range of Android devices can be further improved (Lag keyword).

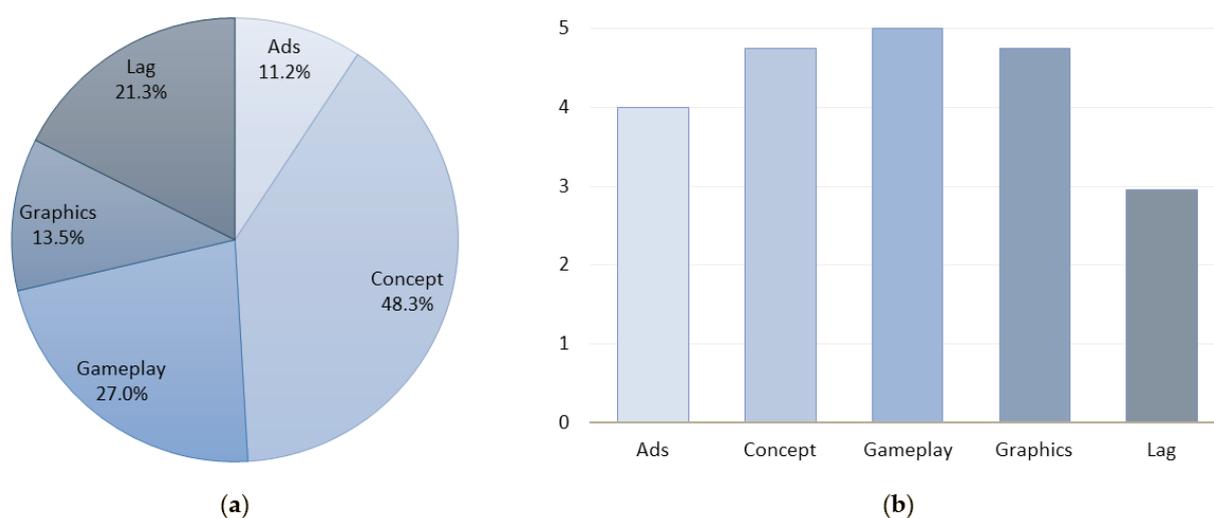


Figure 9. Keywords' percentage (a) and their average rate (b).

It is also worthy to mention that the *Dive in the Past* serious game is currently participating in the annual competition Game Development World Championship (GDWC) 2021. *Dive in the Past* won the "fan favorite weekly game" award for the 18th week of the contest,

and it is currently enrolling for the categories “mobile game of the year” and “hobby game of the year” [80].

5. Discussion

Thanks to this wide diffusion, through the download platforms, it has been possible to receive a high number of reviews from the players who have expressed their personal opinions and offered suggestions about different aspects of the game, such as usability, interface design, duration, game levels, quality of the information, etc. Players’ reviews, in fact, have been collected and analysed in order to identify the presence of critical aspects to be corrected or improved and integrated into the next game releases. What has emerged from the analysis of the reviews is that most of the players have expressed positive opinions and full satisfaction in using the game. In particular, the most appreciated elements are the narrative background, with the historical and the archaeological details integrated within the fictional story and the graphical quality of the game. As mentioned above, the reviews have been useful also to detect issues mostly related to bugs and glitches. In fact, the results depicted in Figure 9 show that “Lag” has not been completely resolved yet. This is mainly because Android devices range from low-end to high-end hardware, with the consequence that the performance of the game is not the same on all devices. Improvements can then be achieved with target-specific optimizations to ensure a consistent framerate on low-end devices, while sacrificing graphical detail to improve performance. Regarding suggestions provided by the players, these have been clustered in the following two main aspects:

- Game languages—the first release of the game had been available in two languages: English and Italian. Users have expressed the desire to use the contents of the game in their mother tongue in order to better understand the information and in particular that related to the historical and cultural aspects. Therefore, Spanish has been included in the latest release of the game, and other languages will be added in upcoming versions.
- Game modes-players enjoyed the entertainment and challenging capabilities of the game; in fact, many suggestions ask for the addition of new game scenarios, levels, and underwater missions. In the same subject, other players have also recommended the introduction of a survival mode to dive underwater freely and explore the submerged sites.

This enthusiastic welcome, coming from different audiences and users, is a tangible proof of the potentialities that serious games, and in particular *Dive in the Past*, can express in the field of Cultural Heritage. As above mentioned, this game aims to enhance underwater sites visibility through multiple interaction layers. The biggest challenge is to stimulate curiosity in people who have very little knowledge about UCH or people who cannot visit them in real life because of physical, economic, or time limitations. In fact, they are not only a virtual environment for gaming and entertainment, but at the same time, they are able to convey information that instructs and informs the player about real places of high cultural and tourist interest that can be visited and enjoyed in real life. In fact, during the game, players acquire historical, archaeological, and cultural information about the underwater sites and the artefacts they contain, and this knowledge helps to raise awareness about the importance of UCH and its protection and preservation for future generations. Furthermore, the connection between gaming activities and real underwater sites will also make the proposed SG an effective marketing tool, stimulating the wider audience’s interest towards visiting the actual underwater sites in real life to learn more about the story behind the game they played.

6. Conclusions

The paper has presented the *Dive in the Past* serious game that has been developed to raise people’s knowledge and cultural awareness of the UCH among both the general public, researchers, and scholars. This goal is achieved through the creation of virtual scenarios that reproduce in a faithful and lifelike way real underwater sites. In particular, the proposed SG allows the player to dive into four underwater archaeological sites

of the Mediterranean Sea by enjoying the experience to swim among the remains of ancient civilizations. The player can explore the underwater sites, while unveiling the narrative stories behind the game, using a first-person view to maximize the engagement. Furthermore, the gaming elements include storytelling, puzzles, and quests to stimulate the player's attention and interest while accomplishing the various missions for each site. The game has been developed for the main mobile platforms, i.e., Android and iOS, in order to allow the widest possible dissemination. Furthermore, it supports the use of the most recent virtual reality technologies, e.g., Oculus Quest, to increase the degree of immersion in the developed virtual scenarios. In the near future, user studies will be carried out to assess the learning impact of the proposed SG by means of qualitative and quantitative metrics.

The connection between gaming activities and real underwater sites will also make the *Dive in the Past* serious game an innovative tourism booster by stimulating the wider audience's curiosity and interest in visiting the actual underwater sites in real life to learn more about the story behind the game they played. In fact, the ever-increasing number of game downloads allows, in this phase of travel restrictions due to the COVID-19 pandemic spread, to play a role of tourist promotion of the four archaeological sites used as virtual scenarios. Further experiments will be carried out in which managers and visitors of the pilot sites will be involved in order to evaluate the impact of the game in terms of tourist attraction. These studies will aim to comprehend how much the game influenced tourists to visit the archaeological sites under investigation and how many of them expressed a new interest and curiosity in underwater archaeology.

Supplementary Materials: The following are available online at <https://youtu.be/B-XdlK1X-n4> (accessed on 14 October 2021), Video: *Dive in the Past* teaser.

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