A Framework to design, develop, and evaluate Immersive and Collaborative Serious Games in Cultural Heritage

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Video games and their design are complex in their nature, given the variety of aspects and challenges to face and the different expertises that have to be involved. Furthermore, Serious Games have an even tougher challenge, since the knowledge acquisition has the same importance and relevance as entertainment and pleasure for the players. Serious Games in Cultural Heritage require additional effort to introduce immersivity and collaboration among players.

This paper introduces a framework, named FRACH, to conceive, design, and evaluate immersive and collaborative Serious Games in Cultural Heritage. In particular, FRACH provides a design framework with steps to follow during the whole process, that is, from the early design phase to the evaluation phase of a Serious Game.

We assessed the efficacy of our framework with a specific case study in Cultural Heritage, by implementing a section of a Serious Game, named *HippocraticaCivitasGame*, where players were allowed to visit the Thermae of the historical site of San Pietro a Corte and Palazzo Fruscione in the city of Salerno, Italy, and to solve a given puzzle. Results of the game evaluation showed that the game was effective in terms of knowledge acquisition, participants enjoyed the game, and were highly involved in the immersive experience, and positively rated the idea of using the game for educational learning in the field of Cultural Heritage.

CCS Concepts: •**Computing methodologies** → **Graphics systems and interfaces; Virtual reality;** •**Applied computing** → **Arts and humanities; Computer games;**

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> "*If history were a photograph of the past it would be flat and uninspiring. Happily, it is a painting; and, like all works of art, it fails of the highest truth unless imagination and ideas are mixed with the paints*" [Nevins 1954].

A large part of the entertainment industry is now absorbed by video games. As a matter of fact, they represent the driving force for growth in several sectors, including also hardware and Information and

Communications Technology (ICT). As pointed out by James Gee [Gee 2009], a video game is essentially an instrument to orient the player throughout a problem-solving place, providing challenging paths to master through entertainment and pleasure.

While games are designed having in mind, at first place, the entertainment and the pleasure of players, "serious" games represent a step in a different direction, being focused on the learning. As such, Serious Games represent an even tougher challenge, since the learning goals, implicit in the design of a traditional video game, are spelled out, identified within a specific content and have the same importance and relevance as entertainment and pleasure for the designer and the player.

In this paper, we study how to design, develop, and validate a Serious Game in Cultural Heritage (CH), by providing a framework, named FRACH , to conduct all the steps from the early design phase to the evaluation phase.

A Serious Game (SG) is defined as "*a mental contest, played with a computer accordance with specific rules, that uses entertainment to further government or corporate training, education, health, public policy, and strategic communication objectives*" [Zyda 2005]. Thus, SGs are games, and what makes them "serious" is the pedagogy involvement with "*activities that educate or instruct, thereby imparting knowledge or skill*" [Zyda 2005]. Indeed, Serious Games have been proven in a variety of applications, including training, education, cultural heritage, health, military and defense. In particular, Serious Games in Cultural Heritage have as applications the historical teaching and learning, or for enhancing museum visits [Anderson et al. 2009].

In education *collaborative learning* is a key concept of prevalent theoretical tendencies related to socio-constructivism, paradigm in which negotiation, dialogue and collaboration are basis for knowledge [Vygotsky 1962]. Hence, ICT used in a collaborative way for educational purpose are taking great importance [Howland et al. 2008] and, more recently, also the Cultural Heritage education has become a field of application for collaborative technological tool as peer-to-peer communication and collaboration in VR context [Ott and Pozzi 2011]. Collaboration and immensity are important qualities to take in consideration to design SGs that involve players in re-experiencing the past and promoting collaborative group learning. As an example we can consider a group of students that visits an archaeological place re-experiencing the past together in collaborative way through the SG, collectively learning.

The design of learning goals achieved through the collaboration among players and the immersivity experience require additional effort during the SG design cycles. Our framework takes into account both collaboration and immersivity in the design of SGs in CH. Players feel the sense of presence, collaboratively living with other players the ancient life through virtual environments. Immersivity in CH has been explored in the literature [Chittaro and Buttussi 2015; Jacobson and Lewis 2005; Jacobson et al. 2009], for instance according to Jacobson [Jacobson 2008], an immersive display provides better supports for learning activities in virtual heritage. About the correlation among immersivity, emotions and knowledge retention, Chittaro et al. [Chittaro and Buttussi 2015] observed that an immersive game increases the knowledge retention as well as the user engagement. Furthermore, according to Merrill, the interaction with real-world activities is one of the five motivation principles [Merrill 2002]. Indeed, as Nevins so evocatively asserts in the quote above, the storytelling about any aspects of ancient life may not be a "photograph" because it is always the result of selection; only thanks to a documented mediation and interpretation the best possible truth can be communicated to the general audience. The effectiveness of communication about the CH value is not only measured through the confidence but also through a medium able to charm and to give suggestions. The problem lies more in awakening the imagination through art than in providing information through a "photograph".

The main contributions of this paper are: (1) an extended Quality model (software quality in terms of ISO 25010 [ISO/IEC-25010 2011]) for SGs in Cultural Heritage, which explicitly adds immersivity and collaboration qualities; (2) an iterative framework, named FRACH, to design SGs in CH taking in consideration immersivity, collaboration and the other qualities, from the beginning of SG's conception toward its whole design; (3) SPLASH, a free, open source, and ready-to-use software platform to use with Unity engine to easily create collaborative and immersive Serious Games in Cultural Heritage. FRACH has been validated through a case study consisting of a SG in Cultural Heritage.

The advantages of our framework are: (a) foster the collaboration and communication among archaeologists, pedagogists, and designer, from the beginning of the Serious Game; (b) stimulate the communication among design actors through the exchange of artefacts (e.g., initial sketch up of the game map, coeval historical data); (c) design by linking together learning goals, immersivity and collaboration (e.g., collaborative puzzles).

The work has been conducted within the project CHIS of the technological district for cultural heritage of Campania region DATABENC (Distretto ad Alta TecnologiA per i BENi Culturali). DATABENC is currently demonstrating some of its results at an exhibition in Salerno with a permanent installation of the *HippocraticaCivitasGame* (described in Section 4) that has been played, from November 2016 to January 2017, more than 2000 times.

The paper is organized as follows. Section 2 discusses some relevant works. In Section 3 we describe the framework that we built with the main goals of designing, implementing, and evaluating SG in the Cultural Heritage field, enhanced with immersivity and collaboration functionalities. Section 4 describes a case study where we applied our methodology on a SG set in the historical place of *"S. Pietro a Corte and Palazzo Fruscione"* in Salerno, Italy [Peduto et al. 2013]. Finally, in Section 5 we conclude with some final remarks and future directions.

2. RELATED WORK

In this Section we describe relevant works in the field of Cultural Heritage and Serious Games. Specifically, we explore three different areas, i.e., existing methodologies to design SGs, existing quality models designed or adapted to SGs, and finally, existing evaluation studies aim at analysing different quality characteristics of SGs.

In the literature, various Serious Game definitions have been proposed [Anderson et al. 2009]. In this paper, we mainly refer to the view that Serious Games are primarily games with an implicit pedagogy component [Anderson et al. 2009; Zyda 2005].

We have to emphasize that, according to the previous SG definition, in this paper we aim to support the develop of SGs, games for training and educational purposes, whereas "gamification" indicates the *use of game design elements (e.g., points, levels, badges) in non-game contexts* [Deterding et al. 2011] (i.e., products and services), to engage users and motivate desired behaviors [Deterding 2012].

According to [Landers 2014], the objectives of both serious game design and gamification of learning are ultimately the improvement of learning outcomes. Although they share a common toolkit of game elements, the process by which these elements affect learning continues to differ. Serious games are designed to fulfill the role of instructor by actually providing instructional content which causes learning. The gamification influences the learning-related behavior or attitude, it is a tool to engage and motivate users. In some sense, players learn from a serious game, but it is not generally valid that they learn from gamification. Therefore, this paper specifically focuses on the design of Serious Games.

2.1 Design methodologies

Development methodology refers to a set of techniques by which a video game is developed. In the literature different game-specific methodologies are available.

As an example, the 5M methodology [Marfisi-Schottman et al. 2009], often used in the engineering field, can be applied to video game development and provides a global view of the SG production chain with its elements. The five Ms of the methodology are the following: *(1) Method*, i.e., sequence of the different production steps; *(2) Milieu*, that considers all the external environment elements or domain expert (e.g., teachers, students, graphic designers and so on); *(3) Manpower*, i.e., the team actors involved in the production chain (e.g., developers); *(4)* the *Machine*, that includes all tools (e.g., software) used during the game production; *(5) Material*, that is, all materials produced or used during the SG's production (e.g., documentation, executable files).

Serious Games are complex in their nature, for this reason, Westera et al [2008] proposed a multilevel approach to face and reduce the complexity for their development. In particular, they identified three main levels to consider, i.e., *conceptual*, *technical*, and *practical* levels. At the *conceptual* level, the game environment is divided into subsystems: the game play world, the learner world, the teacher world, and the game management world. Game play world can be further divided by considering space and dynamics of the game (i.e., changes in the game status) dimensions. In order to face the SG's complexity, our framework presented in this paper, explicitly considers a step named "*Identify Game Logical Scenes*" where the designers face the game design complexity by dividing it in logical parts. This logical splitting can be achieved by using any existing technique (e.g., [Westera et al. 2008]).

Alan Amory [Amory 2007] proposed a theoretical framework, named *Game Object Model* (GOM), to support learning games design. It is based on interrelated components (objects) described as abstract interfaces (pedagogical and theoretical constructs) and concrete interfaces (design elements). The model is structured in five spaces: Game Space, Visualisation Space, Elements Space, Actor Space and Problem Space. As pointed out by Arnab [Arnab et al. 2015], some critical aspects of the GOM are the absence of a clear explanation for how a unit influences another, how contextual factors influence the game and its structure and, because of its generic nature, the model does not offer a specific view on the learning aspects of serious games.

Arnab et al. [Arnab et al. 2015] aimed at providing a more systematic view of the relationship between pedagogical principles and game elements by defining the Learning Mechanics-Game Mechanics (LM-GM) model. This framework is meant to support SG analysis (i.e., identifying and assessing the main features and components of an SG), design (i.e., thinking of what components could constitute a new SG) and specification (i.e., specifying the components of an SG and their relationships). LM-GM include various aspects (e.g., tasks, activities, goals, relationships) that the authors derived from different pedagogical approaches and that an LM-GM user can map to different game mechanics, according to the specific nature of the SG. The model provides a graphical representation of the game flow to build the relationships between the pedagogical components. A limitation of LM-GM is that it does not expose the connection between concrete mechanics and the high-level educational objectives that the game is supposed to attain [Carvalho et al. 2015].

The Activity Theory-based Model [Carvalho et al. 2015], inspired by the previous LM-GM model, aims at offering a structured framework in which the serious game is not an isolated tool but part of a complex learning system that also includes human actors. They introduced a hierarchical structure of activities, grouped into *gaming activity*, *learning activity* and *instructional activity* (instructor point of view). The latter is further subdivided in *intrinsic* instruction (it takes place only inside the game) and the *extrinsic* one (performed outside by the instructor). Furthermore, activities are divided into "serious games components", a sequence of actions, each mediated by tools and goals.

In CH, Bellotti et al. [Bellotti et al. 2012] proposed a model abstracting the SandBox Serious Game, which offers a generalization of task-based learning theory. Moving from the idea to efficiently translate CH contents into a pleasant and educationally effective game, the authors developed a SG where the exploration of a 3D virtual environment with specific CH-oriented tasks (minigames) leads players to acquire educational contents. In learning games the combination of narratives and content has been explored in [Jacobson et al. 2009].

Our framework, differently by the previous described works, has been specifically designed for Serious Games in Cultural Heritage, explicitly considering the immersivity and functional collaborativeness qualities together, which we consider essential to promote group learning. With the specific focus on the Cultural Heritage field, our design framework has steps tailored to it, such as, the collecting of existing domain specific knowledge (e.g., the structure constraints and boundaries) with the integration of data from other coeval historical places. In addition, we provide an open source software platform along with the methodology to easily develop an immersive and collaborative SG.

2.2 Quality in Serious Games

The ISO/IEC 25010 [ISO/IEC-25010 2011] is a quality standard for software, analysis and design artifacts. It contains two models, the "*Quality in use*" model, which considers the software system during its usage (Fig. 1), and the "*Product Quality*" model related to the static properties of the software (Fig. 2). For each model the standard introduces quality characteristics, which can be further divided in sub-characteristics. Each sub-characteristic has attributes to decompose abstract concepts into more concrete ones. Quality in use model considers effectiveness and efficacy which also corresponds to the e^3-learning framework [Merrill 2008; 2009].

The ISO/IEC 25010 has been extended by many literature works in different fields, changing or providing additional quality sub-characteristics. Recently [García-Mundo et al. 2015] proposed a Quality Model for Serious Games (QSGame-Model), which is a product quality model adapted from the ISO/IEC 25010.

A Systematic Mapping Study (SMS) is a well-known research methodology designed to provide a wide overview of a research topic in a systematic and rigorous manner [Petersen et al. 2008]. As an example, a systematic mapping study on SG quality has been conducted by [Vargas et al. 2014]. Authors selected 112 papers in six digital libraries until April, 2013. Their aim was to determine the state of the art in SG quality initiatives and identify gaps to further explore them in next research works. They extracted five main research questions: RQ1) quality characteristics investigated by researchers, mapping them with the ISO/IEC 25010 standard; RQ2) outcome of the research in SGs quality; RQ3) research methods used (validation, evaluation, or non-empirical evidence); RQ4) considered artifacts (requirements, design or final product); RQ5) investigated application areas.

As result, the literature review highlighted that the most evaluated SGs' qualities are the *effectiveness of the knowledge acquisition*, *satisfaction*, and *usability*. Hence, researchers are principally concerned in demonstrating or in confirming that the SG meets its purposes. Furthermore, *playability* is another evaluated characteristic concerning the game enjoyment and entertainment. Other characteristics, such as performance efficiency and security are neglected. An interesting and still unexplored question is the investigation of which playability aspects influence the game effectiveness.

In most works available in the literature, the quality of SGs is considered in the final product (97.32%) after the game design and the development process. As a consequence, as also pointed out in [Vargas et al. 2014], the evaluation of the quality is deferred to late stages. The result is a clear necessity of providing quality assurance methods in order to incorporate quality characteristics since the early stages of a SG design process.

The contribution of our paper in this context is an extension of the ISO/IEC 25010 Quality in use model by adding the *immersivity* (Fig. 1) and the Product Quality by adding the *functional collaborativeness* (Fig. 2). We take in consideration these two qualities specifically for SGs in CH.

2.3 Evaluation in Serious Games

Different systematic reviews have been conducted in the field of SG evaluation. Calderón et al. [2015], by analyzing 119 papers, identified the main methods followed to assess SGs, their application domains, the main categories of SGs, the main features considered to evaluate the educational effectiveness of SGs, the employed procedures, and finally, the size of the population that participated in the assessments. According to this work, the most assessed quality characteristics include usability, learning outcomes, and engagement [Froschauer et al. 2010; Froschauer et al. 2012].

Another important review in the field of SGs has been conducted by Connolly et al [2012]. They analyzed 129 papers with regard to the potential positive impacts of gaming in terms of learning, skill, and engagement. An update of this review [Boyle et al. 2016], where further 143 papers were analyzed in the period from 2009 to 2014, highlighted a more evidence about the positive outcomes of games in terms of engagement and learning.

Backlund and Hendrix [2013] conducted a meta-analysis of 40 scientific studies on the educational effectiveness of games, to determine the types of studies and what they conclude. In the study there is evidence that SGs have positive effect on learning. Interestingly, the meta-study reports that two out of forty studies showed a negative results. About the evaluation of the SGs, often the developer them self carry out the evaluation, whilst in other cases there are independent evaluators (e.g. stakeholders).

Rubino et al. [2015] provided a detailed study on the impact of mobile digital tool in the acquisition of CH contents. They aimed at defining a conceptual framework, designing principles and evaluating the obtained results through the location-based mobile game, developed with the goal of integrating game mechanics and museum objects, with an attention to teenagers' audience. They used semistructured questionnaires to analyze enjoyment and satisfaction, appeal of the game mechanics, usability, and finally, the overall knowledge acquisition. Their main result is the richness of information provided with the game has been appreciated and mostly helped in increasing knowledge acquisition [Backlund and Hendrix 2013]. Educational potentials of SGs and their ability to increase motivation has been investigated by Antoniou et al. [Antoniou et al. 2013].

Many works assessed the immersivity and appeal of SGs [Jennett et al. 2008; Christou 2014; Hassenzahl and Monk 2010]. As an example, Hupont et al. [Hupont et al. 2015] studied how the use of Oculus Rift device impacts on the perceived presence (the sense of being-in the game [Kalawsky 2000]), perceived usability, and emotions in SGs. In their evaluation users interacted with the same Serious Game in two different environments (a PC and with the Oculus Rift). It was also demonstrated that the Oculus Rift broadly increases the sense of immersion and the perceived usability. In addition, they concluded that the perceived immersion is directly proportional to perceived usability.

3. A FRAMEWORK FOR SERIOUS GAMES IN CULTURAL HERITAGE

According to the five learning principles [Merrill 2002] is important to engage learners in learning activities. Toward the application of these principles in Serious Games, we highlight that it is essential to design Serious Games in CH considering *immersivity* and *collaboration* qualities. Through this Section, we extend the sub-categories of ISO 25010 for software quality, explicitly considering these two aspects. Furthermore, designers take them into consideration since the beginning of design throughout all the process. Hence, we introduce a design framework conceived to design, implement, and evaluate SGs in CH, which steps explicitly considers learning goals, immersivity and collaboration as essential aspects to iteratively develop along the design cycles.

3.1 Extended Quality Model with Immersivity and Collaborativeness

In this Section we extend the ISO/IEC 25010 Quality in use model by adding the *immersivity* (Fig. 1) and the Product Quality by adding the *functional collaborativeness* (Fig. 2). This extension is fully compatible with previous works, which extend the base standard considering other quality characteristics and attributes.

Immersivity. The engagement is an important aspect of learning activities. According to the five principles of motivation [Merrill 2002], learning products are effective when they are problem-centered and (a) learners activate their prior experience, (b) there is a demonstration of skills, (c) application of skills and (d) integration with real-word activities. The traditional way is to demonstrate skills (e.g., with classical front-end lessons) but it does not engage the learners. In Serious Games, the player is at the center of the experience, she/he can explore the context, manipulate objects, directly practicing skills is an effective way to construct knowledge [Papert and Harel 1991]. "*Every educator must have felt some envy watching children playing video games: if only that energy could be mobilized in the service of learning something that the educator values... The Constructionist mind is revealed when the wish leads to imagining children making the games instead of just playing them. Rather than wanting games to instruct children they yearn to see children construct games*" [Kafai and Kafai 1995].

An immersive virtual environment can be an effective tool to make the ancient remains for non-expert users clearer and readable, providing information about the results of archaeological research too. An accurate contextualization in realistic 3D settings facilitates situated learning: "*greater visual realism induces greater participant presence*" [Slater et al. 2009]. "*If the player really feels the "sense of place", his or her navigation inside the Serious Virtual World (SVWs) is more effective and the information provided is more credible. Thus, SVWs represent a great opportunity for learning, and it is important that they embed a lot of high-quality contextualized information so that the player can take the most from his or her exploration*" [Bellotti et al. 2010].

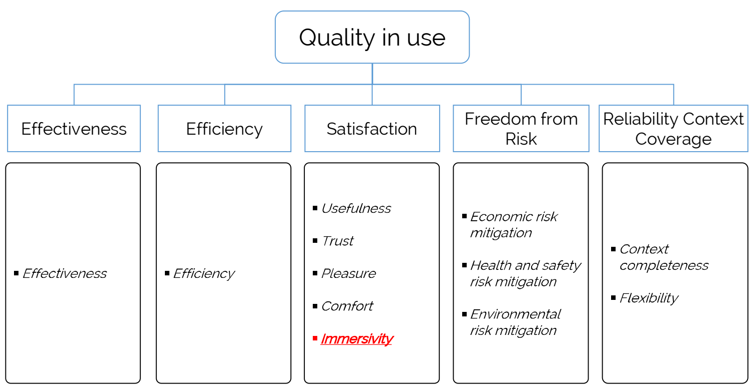


Fig. 1. "*Quality in use model*" (ISO/IEC 25010) extended with the immersivity quality characteristic. The model considers the system quality of the software during its usage.

Functional Collaborativeness. Studies about site visits show that the social dimension is very important in the experience of visiting museums and monuments [Falk and Dierking 2012], in fact most of the tourists is part of a group (family, friends, class group, tour group) and this is true also for users of Italian museums and archaeological sites where 75.8% of guests visit the places of interest in groups [Solima and Bollo 2002]. To give the opportunity to visitors to share the game thus promoting significance of the experience, a key feature of the game is its collaborative structure in multiplayer mode. Of course it is possible also to play individually and to visit the virtual environment having an experience tour. The chance to explore and act as a protagonist in an environment designed in order to build knowledge is crucial for meaningful learning which increases comparing information and collaborating for a common goal in a peer group (collaborative learning). In education this is the key concept of prevalent theoretical tendencies related to socio-constructivism, paradigm in which negotiation, dialogue and collaboration are basis for knowledge [Vygotsky 1962]. So ICT used in a collaborative way for educational purpose are taking great importance [Howland et al. 2008] and, more recently, also the Cultural Heritage education have become a field of application for collaborative technological tool as peer-to-peer communication and collaboration in VR context [Ott and Pozzi 2011]. According to the Dale's cone of experience [Dale 1969], people generally remember, through learning activities, 90% of what they do (i.e., performing tasks [Bellotti et al. 2012]). Hence, *interaction* and *collaboration* are fundamental elements in learning, especially in our knowledge-based society [Harada et al. 1999].

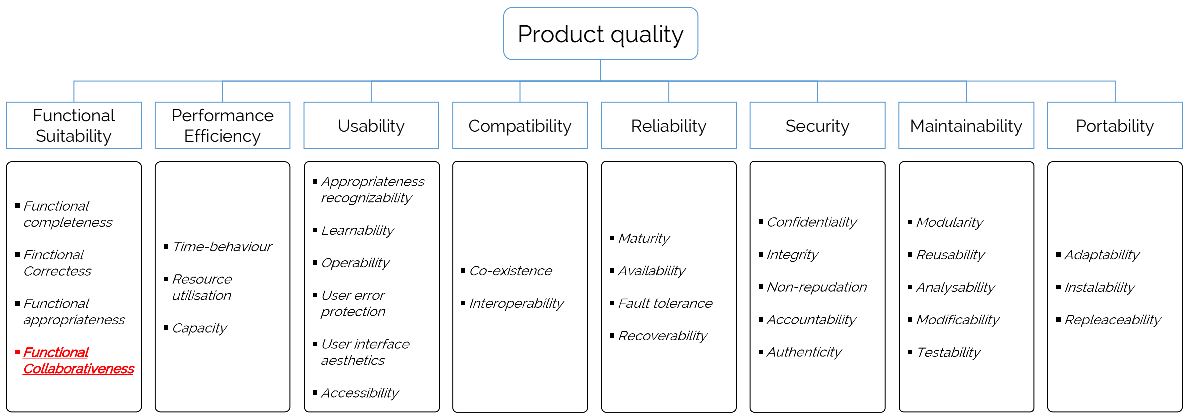


Fig. 2. Product Quality model, which considers static properties of the system.

3.2 Design Framework

This Section describes the framework to design, develop and evaluate SGs for CH. It explicitly takes in consideration the learning goals from the beginning of the design, which is peculiar to the SGs in CH. The framework consists of multiple phases, where each phase is composed of multiple steps. Hence, it is not a single shot process, but an iterative one [Adams 2013]; steps are performed many times, also in various order as well as intertwined. Indeed, the game design is an incremental process, where additional details are gathered, extracted and provided at each iteration. Incremental here also means that the SG is incrementally created by adding content step by step.

Fig. 3 is the overview of the whole framework, which is made by four macro phases, which are: *Preliminary*, *Conceptual*, *Development*, and *Evaluation* phases. The preliminary phase is preparatory and includes high-level steps and reasoning about the whole SG, its aim, target audience and so on. Depending on the specific project, this phase can be less or more demanding. This phase is really creative and can require a consistent period for it. When a project proposal document is already available, it provides helpful information as base to stimulate creativity for this phase. Conceptual, development and evaluation phases as a whole block, can be performed many times to conceive, design, implement and test each of the SG part (e.g. levels).

Each circumference of the Fig. 3 is a phase, and the area can be proportional to the time or costs to perform it. A single phase can be performed many times, as highlighted by the arrows over the dashed circumferences. For instance, steps of the conceptual phase can be iterated multiple times; and at some point, using output generated and decisions made in the conceptual phase to the next phase (i.e., development phase). At some point, when the work done in the conceptual phase is enough to start the

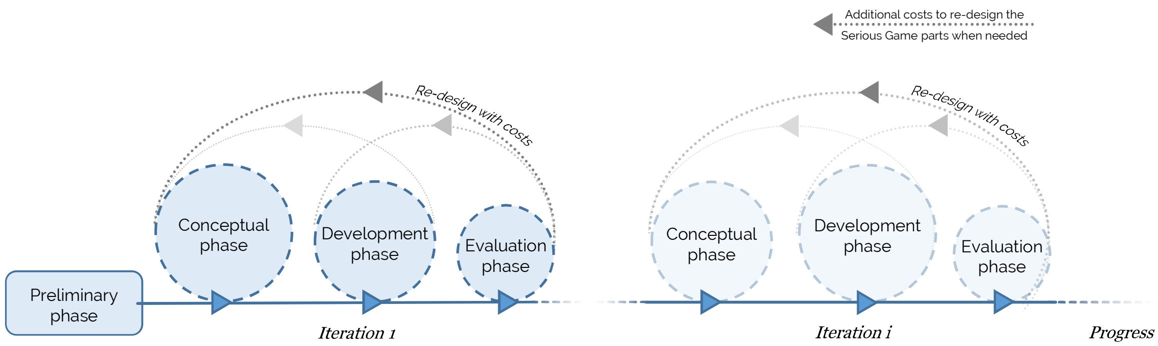


Fig. 3. Framework macro phases to conceive, design and evaluate a Serious Game for Cultural Heritage.

next phase, knowledge gathered in the previous phase is used to perform the next phase (e.g., the development phase). The phases are not strictly sequential, but for instance, during and simultaneously with the development phase, where the game is practically developed, conceptual phase can continue anyway in parallel with the other one.

The design of SGs is a long process involving multiple actors [Marfisi-Schottman et al. 2009]. Actors have multidisciplinary backgrounds and skills, involving domain and content experts (e.g., archaeologists), pedagogical experts, game designers and developers. The communication among these actors is an important aspect as well as a challenge to tackle in every project, especially for the different backgrounds and often the different languages. As reported in [Hickmott et al. 2016], these interdisciplinary teams are likely to have communication barriers. For instance, domain or pedagogical experts, who are usually unfamiliar with the software development, during the design, need to communicate with software developers [Hickmott et al. 2016], who conversely have limited knowledge or experience about learning. Ideas and design is discussed in traditional face-to-face meetings or computer-mediated discussions (e.g., e-mail, videocalls, folder sharing).

Nevertheless the framework's steps have been sequentially depicted in Fig. 4, the specific order depends on the type of game to develop and some steps can be performed in different order as well as return back to previous steps at any time.

All the data and choices made during the SG design are usually collected within the Game Design Document (e.g., following [Roungas 2016]) to share with all the stakeholders. There is no official format for the game design documents [Rogers 2014] albeit some of the sections are common (e.g., challenges section, game resources, etc.). Every game company, depending on the kind of game, has its own design document used to keep track and record design choices before they are build [Dormans et al. 2012]. No standard template emerged that describes how, when or what should be written [Dormans et al. 2012].

3.2.1 *Preliminary Phase.* Preliminary phase is the initial step that aims to perform all the activities before the starting of the main conceptual phase. It aims to have an initial idea as well as a description of the SG idea, its audience and what is the main learning goal.

Brief and broad description of the Serious Game and its goals. A brief description of the SG, with details about the idea and its aim is an essential initial artifact to share among stakeholders and designers. It is the starting point to elaborate the next steps. This description identifies the historical context (e.g., archaeological site, historical epoch).

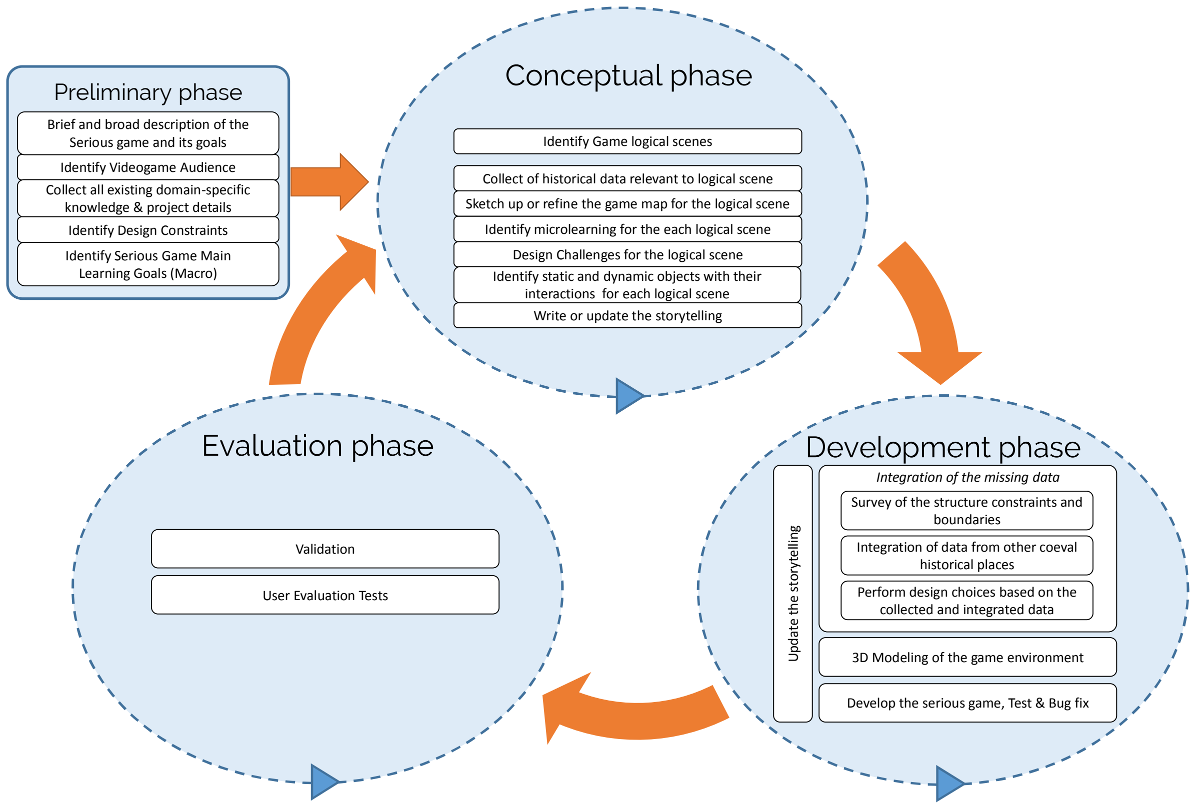


Fig. 4. Framework steps to design, implement, and evaluate Serious Games for Cultural Heritage.

Identify Serious Game Audience. This initial step is essential and aims to have a clear idea of *who and where players will play and learn through the serious game*. This should be already known by the brief serious game statement, but it makes clear and evident who will be the target users and which players will be willing to play with it. Audience could be for instance, visitors of a museum or a showroom, or students.

Collect existing knowledge & project details. This step considers the collection and systematic organisation of the existing project information. In particular, many of the data details could be already described within the project proposal. This steps involves all the domain and pedagogical experts, stakeholders, and designers. For instance, in this phase the archaeologists can collect all the information about the archaeological site (e.g., historical period, plan of the existing archaeological site).

Identify and categorise Design Constraints. Design constraints can be of various nature, such as, budget, domain constraints, location. Constraints are reported by stakeholders and directly impact the serious game design, final product, and must be satisfied by the game design. Of course, it is not easy to extract all constraints at once, but other can emerge during the design and meeting with stakeholders. Our methodology considers the identification of design constraints from the beginning of the serious game design because they can seriously impact the design and can not be postponed during the design. Constraints here also refers to the quality characteristics to achieve; for instance, the guarantee of a specific degree of immersivity.

Identify Serious Game Main Learning Goals (Macro). This step aims to identify the main learning goal for the entire game that in some sense motivates why the serious game must be designed. For instance, a main learning goal for a SG in CH with an immersive virtual environment could be to provide to the user direct indications about the set and the historical age related to the site of interest. That is even more true when the game has different layers settled in different periods.

3.2.2 *Conceptual Phase.* The conceptual phase is the main phase where the requirements are collected, and the game conception and its design starts.

Identify Game logical scene. The SG to design is divided in multiple logical scenes. A logical scene is a consistent, self-contained, and logically separable piece of the game to be designed, developed and tested across the proposed phases. Hence, the game is made of many logical scenes. An example of logical scenes subdivision are the game levels. In order to identify logical scenes different techniques can be used. Authors in [Westera et al. 2008] described a common way to logically split game in multiple parts and face its complexity. They divided the SG in chapters, scenes, and scenarios. In order to face the SG complexity, the idea is to identify the game logical scene, select one of them and perform the whole cycle of conceptual, development, and evaluation phases. In this way, the divide et impera design pattern is applied.

Sketch up or refine the game map for the logical scene. In order to support discussions and boost creativity, it is very helpful to have a sketch up of the game map. This map can be provided by archaeologists. Of course, especially for CH, when considering archaeological ruins, information on some parts of the site are not available and must be integrated with information from other coeval places.

Identify micro-learning for each logical scene. For each logical scene, the aim is to identify one or more micro-learning goals. Challenges are then designed to meet those micro-learning goals. An example of micro-learning goal is the understanding about the function and the development of the ancient structure. In this sense, placing items related to the ancient every day life (i.e., foods eaten, lighting systems, furniture) is an effective way to convey such knowledge. In addition, the direct interaction with some of these objects can convey habits of ancient peoples.

Identification of objects, interactions and design of challenges for the logical scene. The challenges or puzzles in a SG are very important because the player acquires knowledge by solving them. The micro-learning goals define only what the player hopefully will learn playing it. The design of challenges define how they will target the learning goal. The design of puzzles is not easy, it involves all the experts, and must take into account the domain knowledge, pedagogical aspects, and technical constraints and feasibility. The design of challenges is a creative process, but a way to foster and start their design is to consider the archaeological objects and their interactions.

3.2.3 *Development Phase.* Obviously the first step for designing a serious game which enlarges awareness of CH (in general) through a single site (in detail) is to gain a deep knowledge of it. This is required to identify the core of its value and relevance, i.e. the essential elements to be imparted. For this reason it is necessary to work closely with domain experts who can provide highlights and general interpretations of historical layers of the site of interest but also detailed data useful for the reconstruction of a trusty gaming environment and, more in general, for dissemination of validated content on scientific basis. This first stage is aimed to get an effective survey of documentation which consist in three kind of data: informations from archival sources; archaeological data about structures and finds provided through scientific excavations and iconographic sources (painting, miniature, artcraft). It is not always possible to get whole documentation in digital format but to have the planimetries and layouts in CAD or digital models of particular artifacts it's necessary to start designing and building the game virtual environment. The following creation of the game's plot takes advantage of the survey about historical layers of the site not only to recognize the elements identified as learning goals but also for the choice of the structure of the game.

Survey of structure constraints and boundaries. Even the highest degree of conservation of an ancient site and the most accurate documentation can not guarantee a perfect confidence in virtual reconstruction. At some point the deficiencies of the information come out and CH domain experts and 3D artist have to take choices to implement the virtual environment set of the game. This decision process cannot be arbitrary so the integration of the missing data is obtainable through survey of structure constraints and boundaries and comparison with other coeval historical place. Some structural features - such as the length of the wooden beams, number of sustainable levels - arise limits to the possible interpretations; this shows the importance of working in a multidisciplinary team. Another boundary not to be exceeded is the assembly of an ancient environment in which the hypothesised elements overshadow those in situ.

Integration of data from other coeval historical place (parallels). If it is impossible to recover structure and features, the model can be integrated with solutions from contemporary examples in the literature or still preserved (parallels). Caution is needed: the supplements do not have to devalue objects and decorations in situ and should belong to the same geographical area. The goal is to inform the user about what has been recovered during the survey phase of the data on the site and about all that has survived of the original structures. The phase of data integration is particularly difficult because it has to do with the problem of the level of confidence [Reilly 1992]. There is a large section of studies that have raised the issue: reconstructive models are interpretative and so "visual (computer) models should make clear their sources and the criteria on which they are based" [Niccolucci 2002]. These are the same orientations of the international charters that set the principles and guidelines for the computer-based visualization of CH items [ICOMOS 1996; Charter 2009; Denard 2012; Charter 2010]. Working in every step with archaeologists, historians, and art historians the problem of provenance and of confidence of the virtual reconstruction continually arises during the modeling. This point risks becoming paralyzing for those wishing to operate in a philological way: a margin of interpretation, especially for items not documented is needed to typify the game setting. Especially when the reconstruction is functional to a game environment the main objective is to create a pleasant setting, coherent and oriented to the dissemination of validated content; this can not be always achieved visualising the ruins existing in situ only.

Perform design choices based on the collected and integrated data. On the basis of the collection of the documentation and of the study for philological integrations, the necessary data for construction of the model are provided to the 3D artist. Eventually his comments and difficulties are to be reexamined by the expert of CH. Always combining the virtual environment efficiency of game and the highest confidence possible, a new solution is negotiated.

Develop the Serious Game, Test & Bug fixing. From technical point of view, an essential and crucial step is the identification of the game engine [Lewis and Jacobson 2002] to use. The game engine selection can be based on various criteria, for instance its licence, openness and interoperability with other platforms, the cost [Henriks 2007], available of tools [Tan et al. 2005], direct support of virtual reality or through additional libraries (e.g., CaveUT [Jacobson and Lewis 2005]). Furthermore, methodologies for the game engine selection have been discussed in the literature [Petridis et al. 2012; Anderson et al.

2013]; for example Anderson et al. [Anderson et al. 2013] proposed the white room approach to compare different engines, exploring also the development complexities. This step refers mainly to short iteration that aim to develop the game as a whole.

3.2.4 *Evaluation Phase.* A generic evaluation methodology, to allow standardization, should include: (1) what strategy use, e.g., validation with experimental research or evaluation (2) what methods and procedures use, e.g., questionnaire, interview, focus group, and so on.

More specifically, a standardized methodology should allow a clear formulation of the research questions or the quality characteristics that have to be assessed, an accurate planning of the appropriate research design, a reliable user testing process; (4) a reliable analysis with reproducible results.

The main quality characteristics [ISO/IEC-25010 2011] to assess when evaluating SGs, include game design and interfaces in terms of aesthetics and interactions, user satisfaction, usability, usefulness, playability, engagement, enjoyment, user experience and acceptance, efficacy and performance, pedagogical aspects and learning outcomes. Educational effectiveness in terms of knowledge acquisition is the most assessed quality, followed by user's experience and usability [Calderón and Ruiz 2015].

Several types of research studies can be performed to evaluate a serious game. As dictated by the human-computer interaction research field (HCI) [Jonathan Lazar 2010], the type of research may be of three different types: descriptive, relational, and experimental. Research may involve combination of two or even all three kinds of investigations. Moreover, experiments can be of different types, that are, experiments, quasi-experiments, single-condition studies, case studies. In a descriptive or relational study the typical used research methods include observations, field studies, focus groups, interviews. In an experimental type of research controlled experiments have to be carried out.

Questionnaires represent the main method used to evaluate serious games [Calderón and Ruiz 2015]. Pre-test and post-test can be performed to understand what participants know before using the SG and what they know after. Longitudinal studies may involve multiple trials to assess the level of retention of learned knowledge.

Standard questionnaires, available in the literature across all fields of research, can be used to assess SGs. They include questionnaires to measure user's experience in immersive gaming [Lessiter et al. 2001; Moser et al. 2012], cognitive and affective experiences [Watson and Clark 1998], user's satisfaction [Chin et al. 1988], user's engagement [Brockmyer et al. 2009], user's acceptance [Davis 1989], motion sickness [Kennedy et al. 1993], the perceived presence inside virtual environments [Witmer and Singer 1998], the usability as perceived by users [Lewis 1995; Brooke 1996].

4. HIPPOCRATICACIVITASGAME: A CASE STUDY

This Section introduces our Serious Game, named *HippocraticaCivitasGame*, set at Palazzo Fruscione and San Pietro a Corte, in the city of Salerno, Campania Region, Italy. It has been developed following the steps dictated by FRACH described in Section 3. The Section describes in detail the first two levels of *HippocraticaCivitasGame*, specifically referring to the immersivity quality.

4.1 Serious Game description

Our SG is set at Palazzo Fruscione and San Pietro a Corte, in Salerno, which is plurilayered archaeological site with different historical periods (i.e., Roman, Longobard, Norman and Angevin). These differences impact on the architectural style with a variety of archeological and historical elements, which is usually difficult to perceive for common visitors. Many of the elements are hidden, and can not be visited because they were covered after the excavation of the site to preserve their conditions. Thus, the idea to design a Serious Game to convey (macro learning goal) the site heterogeneity and its complexity over time while playing. During the SG design we identified four game levels, the first one

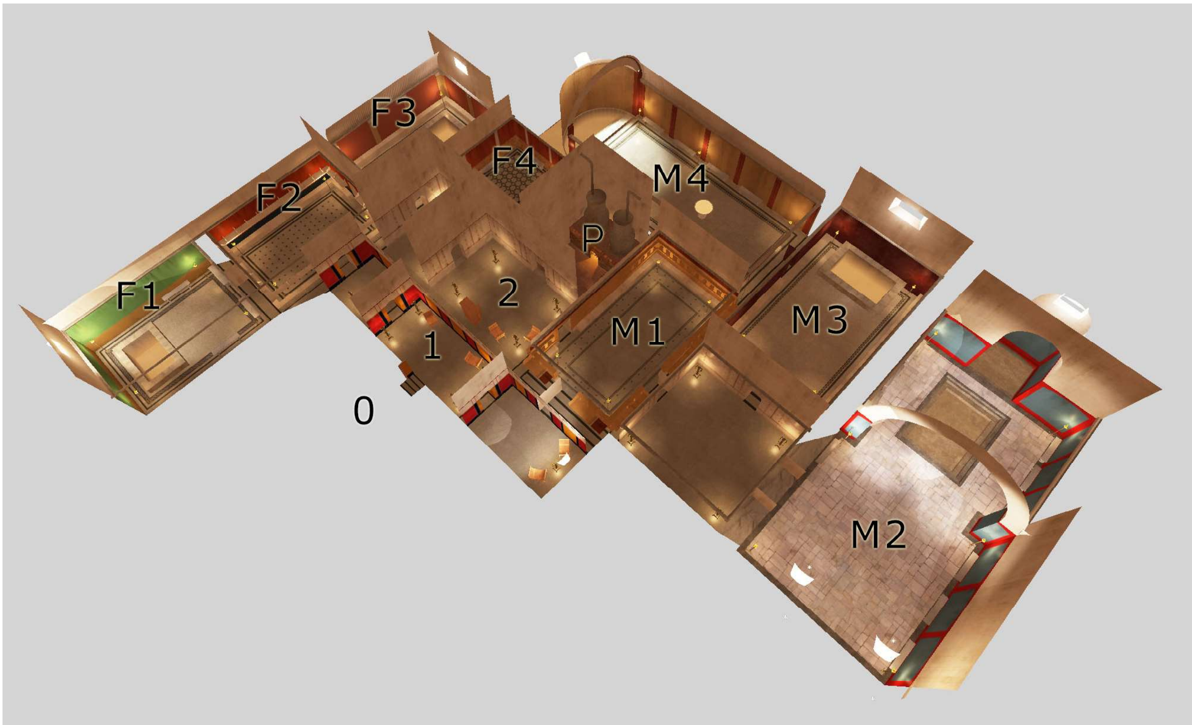


Fig. 5. The map of the Thermae level, set at Palazzo Fruscione and San Pietro a Corte, in Salerno. The rooms are: atrium, vestibule and room with cabinet (0-1-2); female *apodyterium* (F1), *frigidarium* (F2), *tepidarium* (F3), *caldarium* (F4); male *apodyterium* (M1), *frigidarium* (M2), *tepidarium* (M3), *caldarium* (M4); *praefurnium* (P).

is the external atrium for the initial training with game devices; the others are the Roman Thermae (I A.D.), Palatine Chapel of Arechi II Palace (VIII A.D.), Chapel of Santa Caterina (XIII-XIV A.D.). In this case study we will describe the first two levels of the SG.

Learning goals. Besides the macro learning goals, we identified micro learning goals for each level as highlighted in the design framework (Section 3.2). Players achieving the micro learning goals will acquire single piece of information that together will convey the site complexity and its plurilayering. The micro learning goals are: 1) in order to enter in the Thermae, the customer pays with coins of the Roman period (*as* and *quadrans*); 2) Thermae had a zone reserved to men and another one (smaller) for women; 3) urban Thermae usually included four facilities, *apodyterium* (dressing room), *frigidarium* (for cold baths), *tepidarium* (for warm baths), and *caldarium* (for hot baths), corresponding to the various phases of the Roman thermal bath; and 4) tools used (i.e., strigil, towels).

Game environment and challenges. Fig. 5 shows the Roman Thermae SG level map. Thermae ruins of Palazzo Fruscione are concretely visitable, but only two rooms are effectively there: one room with a Roman mosaic imagined as *caldarium* (room number F4 in Fig. 5) and the underlying room of San Pietro a Corte has been interpreted as *frigidarium* (room number M2 in Fig. 5). Hence, the SG mixes historical elements that are well-known and are in situ with other coeval elements adopting the steps described in the design framework (Section 3.2).

Fig. 6. Strigil tool in the cabinet of the *apodyterium*.

The players start in the Thermae's atrium. They need to find the Roman Coins to gain the access to the Thermae, achieving the first learning goal to recognise the coins and that in order to enter a payment is required. There are two types of coins: *as* and *quadrans*. A *quadrans* enables access to a single player, the *as* detection, however, authorize the entry for the whole team when you are in multiplayers mode. It is accessed within the thermal bath through a vestibule (room 1 of Fig. 5) that leads to two corridors leading to the women's section or directly or to the male which is separated. The two sections have *apodyterium* (dressing room), *frigidarium* (cold water bath), *tepidarium* (warm water bath) and *caldarium* (hot bath). At the center of the room there is the boiler that feeds the pools of the two *caldarium*.

Among the selected micro learning goals for the SG, one is the explanation of main the tools used within the Roman Thermae. Thus, the challenge for the players is to find the strigil (Fig. 6) in the game environment (Fig. 5) and place it in one of the two *apodyterium*. The strigil is a tool for the cleansing of the body by scraping off dirt. Through this challenge the player has the opportunity to observe the tool and learn its use. In order to evaluate the effectiveness of this challenge in transmitting this micro learning goal we conducted an evaluation described in Section 4.2.3. The feedback and results of the evaluation of this micro challenge is the foundation to design and implement other challenges, for instance, the stoke of the fire with pieces of wood in the *praefurnium*.

4.2 Serious Game Design

In order to design our SG case study, we followed the design framework (Section 3.2) with two iterations. The first iteration to design the training level that is the atrium, where the players start the game. The second iteration to design the Roman Thermae level. The initial conceptual phase required many meetings to collect all available information, to identify the macro and learning goals to convey the archaeological site structure stratification over time, and to conceive the game.

4.2.1 *Conceptual phase.* Archaeologists collected all the information on the site: the topographic map, books, photos, stratified cards, and documents. The topography map has been used to identify two sites to place within the game, which are the Roman parts identified in Palazzo Fruscione and San Pietro a Corte. In this paper, we focus on the Roman phase. However, the site is actually plurilayered, having on the same place elements of the medieval period. Only a part of the entire archaeological site is known, that forces the integration of information from other coeval sources both for the structural part and objects; it had required a strong effort to fill this gap by the archaeologists. The output of this phase was a map of the site based on the topographic map and mixed with reasonable presumed elements (based on pre-existing ones). Map heavily used during meetings with the other experts to discuss the SG goals, storytelling and puzzles.

Domain experts collected and provided to the other team experts the map, historical information, photos and descriptions of the site and objects with their possible usage. Therefore, from this information many micro learning goals have been identified, but of course some of them have been discarded, and finally we extracted the target micro learning goals detailed already described in the previous Section 4.1. Identified these micro learning goals, the focus moved on the challenges to introduce within the game to acquire the knowledge. In order to foster the creativity on how to effectively design challenges we used the objects and their interactions suggested by the domain experts. For instance, in order to transmit knowledge on which tools the Romans used within the Thermae, we selected the strigil. For the players, the challenge in the game is to find the strigil understanding its aim. These challenge to find an historical object and play with it acquiring the knowledge is a pattern reused also for other object and game levels (i.e., find the wood to stoke the fire of the boilers in the *praefurnium*). The players have micro information shown as messages on the screen on the goals to achieve.

4.2.2 *Development phase.* This phase aims to develop the *HippocraticaCivitasGame*, modelling the SG environment (i.e., atrium and Thermae) and implementing its features, logic, and challenges. For the modelling part, the graphic designers together with archaeologists iteratively designed the game environment model based on the information collected and integrated in the previous steps. It requires many iterations, which starts with the sketch up of the environment, building of structure, choosing of the textures and furnishings. In this step, it is fundamental the continuous participation and collaboration with the domain experts to guarantee the coherence of the model and, in particular, they can immediately provide feedback and missing information.

For this task we developed a read-to-use, free and open source platform, named SPLASH, released under the CC BY-NC-SA license. Instead to start from scratch and deal with the development complexity, our platform provides reusable, modular, and extensible building blocks to introduce *immersivity* and *collaboration* among multiple players within the SG. Along with the platform source code, that is published on GitHub[1], we also provided a simple demo. The HippocraticaCivitasGame is based on the SPLASH platform. The following sub-sections introduce this platform architecture and its features.

Platform Architecture. The platform supports the collaboration among players, each one using a different input device, such as, keyboard, Joypad, Oculus Rift (via head movements), Kinect. Fig. 7 shows an example of three computer installations each one with a different input device and interconnected via a high-performance network switch. Players can play together by using the Oculus Rift and a joypad, the Oculus Rift and the Kinect, and the joypad only.

Technically the platform is based on the Unity Game Engine[2], a cross-platform engine to develop games. Our platform provides, in addition, easy-to-use and reusable compontents to develop immer-

[1] https://github.com/isislab-unisa/serious-game
[2] The official Unity game engine web-site is https://unity3d.com/

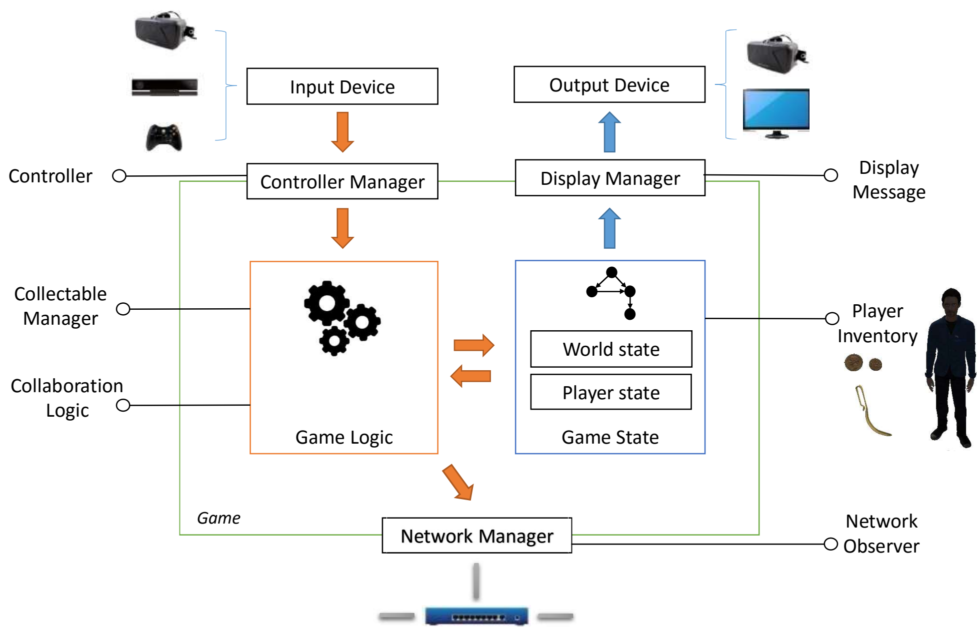


Fig. 7. The software platform architecture: components and interactions.

sive and collaborative games. Fig. 7 shows the platform architecture with its reusable components to manage the different game aspects (e.g., input, output, network, game logic and so on). When a player interacts with the game through an input device, this interaction is translated in a performed action. The *Controller Manager* receives the input commands, processes and sends them to the game logic. The *Game Logic* coordinates and synchronises the different game components. In particular, when it receives commands from the Controller Manager, it handles the input command and triggers action events to the other components. This action event may change the world and the player states (Game State) that are defined by the roles in the Game Logic. The *Game State* stores the entire game status in terms of actor state and the entire world state. The Game Logic also defines which state must be shared among players through the *Network Manager*. The Network Manager implements the collaboration among players. The *Display Manager* renders the game independently from the output device (e.g., Oculus Rift or Monitor). Thus, collaboration and synchronization are performed through a central server based on Photon Unity Networking[3] to synchronise the game status of the dynamic objects on the different instances (i.e., clients). It provides a simplified management of objects and players states, using Remote Procedure Call (RPC) paradigm. RPC is the invocation of procedure (subroutine) on another address space (i.e. another computer on network).

Collectable object centric view. SGs in CH are designed with learning goals in mind, implemented through game puzzles that require players to interact with dynamic objects. Furthermore, in collaborative SGs, the state of these dynamic objects as well as interactions must be synchronised among the

[3]Photon server web-site is https://www.photonengine.com/

all client instances. Thus, our software platform has been designed around the concept of *collectable objects*, providing building blocks to transform game objects in collaboratively collectable objects.

The collectable centric view assumes that the logic to synchronise players' actions are defined on the object itself. In particular, the collaborative and collectable features are defined within prefabs (level geometries) for modularity purposes. Prefabs are reusable modules. Each prefab is a template to create new object instances in the scene. Any change made on a prefab asset is immediately reflected in all its instances. Each prefab defines properties, which allow the customisation of objects instances created from the prefab itself. In addition, the Unity Game engine allows the attachment of scripts to the prefabs to be shared across multiple object instances. In order to make an object collectable, it must have a collider and a *Collectable Manager*, which defines the logic of the interaction between object and players.

Our platform also provides the inventory for the players in form of prefabs. In this way, any collectable object can be automatically added to the player collection. This has been implemented with a state machine based on the object status. In order to enhance the player with the inventory, the platform provides a PlayerInventory Script.

Player features. Our platform provides the basic game feature (e.g., movements) that any player must have as well as enhanced features to manage the inventory, actions and synchronisation. For instance, when the user player presses the associated button to pick up an object and the avatar is close to the target object, it will collect the object. The avatar status (e.g., position and rotation) with its animation (e.g., walking) is synchronised, using the PhotonView component, across the client instances. In the *HippocraticaCivitasGame* the *Action* allows the user to open a cabinet and pick up the strigil. The strigil object contains a *Collider* that indicates the area in which the player can interact with it. The strigil has also a *Collectable Manager*, which contains the collectable logic that describes how to interact with it. The display message manages all the textual and sprite content to be shown to the end user. For instance, when the player picks up an object, the display message shows the feedback.

SPLASH Platform usage and analytics. In this platform there are two sample scenes (simple one and advanced one), and prefabs (e.g., players) with relevant scripts to provide immersivity and collaboration, whence the developer can start. Developers simply can drag and drop prefabs and scripts within the current developing game. For instance, in the case of *HippocraticaCivitasGame* those prefabs have been used for Axis, Quadrant coins.

SPLASH platform provides base scripts to share the objects' status across the network to implement collaboration among players. Those scripts can be dragged and dropped on the objects to synchronise across the network. For instance, in order to share the strigil status in *HippocraticaCivitasGame*, the developer simply drags the script for sychronization on the strigil object, getting immediately the feature. In this way players, who play on different instances of game (multiplaying), have the same vision of the scene.

SPLASH platform provides a system for the logging of user interaction, which can be used to analyse the player movements and actions as well as create the HeatMap to show most visited places in the map. Other information (more specific) can be found in the readme file.

Starting from this platform, in synergy with other professional figures such as archaeologists, graphic designers and computer scientists we have made this serious game. Starting from the scenes provided on Git, leveraging the collaborative elements and scripts on objects available on Git. The graphic designer shaped environments (with 3D Studio Max) "brought back to life" by archaeologists works (through photos and artifacts). From the computer scientist point of view developer have to know the dynamics of a game (even if Unity is simple to use and makes available many tutorials), and the network concept to better understand the sharing of the states of objects across the network. This work has involved us for about three months. Developer can use the platform made available to simplify understanding of the dynamics and of the aspects that we have identified to simplify the planning and development of a seriuos game using the strategy (pattern) that we have developed such as collectable object centric view.

4.2.3 *Evaluation phase.* The aim of our evaluation study was to assess the following qualities: (a) the effectiveness of the experience in terms of knowledge acquisition when addressing a specific micro learning goal; (b) efficiency in terms of responsiveness and naturalness of controls; and finally (c) user's satisfaction (see Fig. 1). These qualities have been fixed at the early stage of the design of the game and follow the FRACH framework. About effectiveness, we evaluated the understanding the use of the strigil and how the Thermae are structured, by finding the strigil in a cabinet and moving it in the *apodyterium*. About satisfaction, we assessed users' perceived immersivity and playability during the virtual experience. Finally, we analyzed the cybersickness during the immersive experience deriving differences in terms of several factors, such as, gender, age, previous experience with videogames. We first describe the methodology that we employed for our evaluation study, afterwards we discuss the results obtained when a group of 72 people was involved in testing *HippocraticaCivitasGame*.

Method. Our study took place in a large, dedicated space in a research laboratory at the University of Salerno. The workstation used for rendering the environment was equipped with an i7-4770K 8-CPU, a Nvidia GTX770 Graphics card, and 16GB of main memory. The input device used was a wireless Microsoft XBOX 360 Controller. The virtual reality headset supported was based on the Oculus Rift.

The study envisioned three different phases in which we carried out: (a) a Preliminary Survey (b) a Testing Phase and (c) a Summary Survey, as defined and implemented in other contexts [Malandrino et al. 2013; Malandrino et al. 2014; Fish et al. 2016].

As first step, participants filled out a preliminary survey questionnaire about their demographics (i.e., gender, age, education level), video gaming experience, and eventual sensitivity to the kinetosis problem. The questions included in this questionnaire (and listed in the "Preliminary Survey" Section) were questions asking to give a preference up to 12 possible choices and questions with a rating on a 5-point Likert scale with *Inexpert*/*Expert* as verbal anchors.

Thereafter, participants were briefly informed about the task to perform. This task, corresponds to the micro learning described in Section 4.1. They had a fixed amount of time to complete the task (i.e., 5 minutes). When this time expired, interested participants were anyway allowed to continue the virtual experience. At the end of the testing phase we asked users to fill in a questionnaire, adapted from the standard *Presence* Questionnaire [Witmer and Singer 1998], aiming at assess the perceived degree of involvement and enjoyment. From this questionnaire we extracted questions (listed in the "Immersion, control, and playability" Section) that allow to obtain sub-scores in terms of three factors: realism (Question 22), control (Questions 15, 16, 21), and involvement (Question 20). Each question was a rating on a 7-point Likert scale with *strongly agree* and *strongly disagree* as verbal anchors.

In addition, performance data were collected during the gaming experience with scripts implemented in the SG. Specifically, we logged, for each participant, the time when she started the experience, the time when she found the strigil, the time when it was arranged in the requested place, and finally, the time when the experience finished.

In the last phase we asked users to fill in a summary survey aiming at gather users' perceptions about the usefulness of this SG for educational purposes and their propensity to recommend the game to a friend (7-point Likert scale). We also asked participants to provide the definition of the strigil (we provided 4 different choices, just one correct). In this last phase we also studied the effects of cybersickness, the digital version of the motion sickness, by administering a questionnaire adapted from the standard *Simulator sickness* Questionnaire [Kennedy et al. 1993]. From this questionnaire we extracted some symptoms asking participants to rate their corresponding severity levels, from *None* to *Severe* (questions listed in the “Summary Survey” Section).

All administered questionnaires, translated into English, are available online[4], while the whole evaluation study lasted approximately 40 minutes.

Subjects were students, teachers, and employers at several departments of the University of Salerno. They were recruited through flyers and word of mouth advertising. Their participation was voluntary and anonymous. They were informed that they could stop at any time during the evaluation process, and that all the information they provided would remain confidential.

Results. A total of 72 participants were recruited from the general campus population (49% Humanities, 51% Science). The sample was mostly male (64% male, 36% female) with a mean age of 27 (SD = 8). 67% of participants reported intermediate or higher experience with videogamaes, 21% stated to be expert, while only 12% reported a low experience in that field. 35% reported to be prone to motion sickness (we did not find any statistical difference with regard to the gender factor). Finally, the entire sample had no confidence with the Oculus Rift device.

Results of the Testing phase showed that 80% of participants was able to find the strigil, but only 64% was able to put it in the right place. On average, it took about 2.5 minutes (SD=1.2) to find the strigil, and about 63 seconds (SD=0.9) to put back it in the right place. However, almost all participants (96%) were able to successfully respond to the question about the definition of the strigil that was the aim of our micro learning goal. This result suggests that participants paid attention to the messages conveyed during the experience, although they stated to be very involved in the game (M=6.3, SD=1.0).

During the Testing phase, in addition to performance data, we also collected information about users' movements. The analysis of behavioral patterns could be useful to understand where messages, interactions, point of interests have to be spotted in order to foster learning of a specific element inside the historical/archaeological site.

As we can see from Fig. 8, the areas highlighted in cyan color represent the areas of the entire map rarely visited, the red zones are the most visited ones, while in the middle between them, we have the yellow areas. The heatmap shows the starting point colored in red. In addition, the most used itineraries are obviously those needed to complete the assigned task. The less visited places are the *caldarium* and the *apodyterium*. Lack of information in these places, highlighted with the heatmap, could be addressed by intervening with specific messages, interactions, and so on, that is, with other specific micro learning goals.

In Fig. 9 we report the results of users' perceptions about playability (Questions 9, 10, and 11 in the “Immersion, control, and playability” Section), the control they had within the game, and their motivation. Reliability values (Chronbach's Alpha) in terms of all participants answers is 0.76 (above the recommended value of 0.70 given in the literature [Jum C. Nunnally 1994]). We did not find any statistical differences with regard to these metrics when considering the gender factor.

About the *Control* factor, our sample agreed with how easy was to use the Oculus (*“I found the field of view rotation using Oculus Rift - head movement - very easy to perform”*, M=6.1, SD=1.4) and expressed high satisfaction in terms of the sensitivity of the controller (*“The game controller sensitivity in the virtual experience was adequate”*, M=6.0, SD=1.1). Similarly, the *Motivation* factor was positively rated by our sample (M=6.5, SD=0.7).

Participants found out responsive the overall system (M=6.5, SD=0.8), and they perceived very natural the interactions within the game (M=6.0, SD=1.0). What is really remarkable is that, despite participants had little time to play, they rated very positively their involvement as well as their in-

[4] http://www.di.unisa.it/~delmal/research/usability/JOCCH2016/

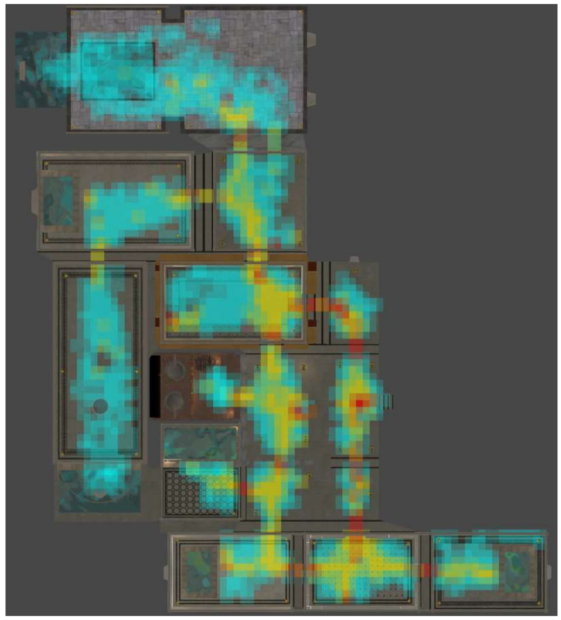


Fig. 8. Heatmap of participants movements along the possible itineraries. It corresponds to the physical map shown in Fig. 5.

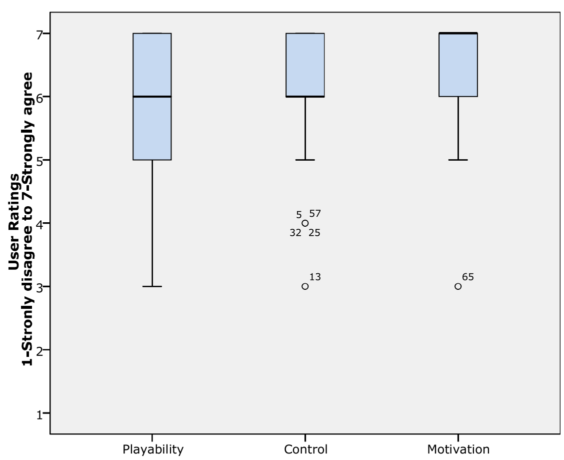
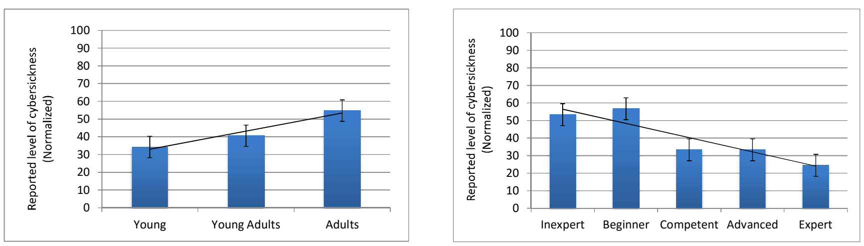


Fig. 9. Playability, control & motivation.

creased ability at the end of the experience (M=5.6, SD=1.5), highlighting the easiness of the controls that we designed for the game. The *Realism Factor* was highly positively rated, as also derived by informal suggestions at the end of the evaluation process. 35% of participants, in fact, provided as positive aspect of the overall experience, the accuracy of the 3D reconstruction, and how much "real" the virtual experience was perceived.

Results about cybersickness, showed that dizziness was the symptom most felt by the participants at the study (44%). Nausea was the second most felt symptom, with th highest degree of severity (7% felt the nausea with a sever level). Only 20% of participants did not suffered of any type of problem.

As further analysis, we classified participants in three groups, namely, "*Young*" (with the age range 19-25), "*Young Adults*" (with the age range 26-31), and "*Adults*" (with the age range 31-60). Our *Adults* users were also the less familiar with video games and immersive systems (4 experts in the older group against 11 in the young one). Interestingly, we found out a correlation between age and reported sense of general discomforts due to cybersickness. (see Fig. 10(a)). We also found out a correlation between the feeling of discomforts due to cybersickness and the experience of the users with virtual immersive environments (see Fig. 10(b)). Oculus Rift devices have not completely penetrated the consumer market, but they will become more and more popular in the next few years. As a consequence, users will start to get used to them, and therefore, cybersickness could be reduced through training and established experience. However, a longitudinal study, with a large and diversified sample of participants, is needed to study these effects. Finally, we did not find any statistical differences among the three groups of users in terms of playability, control and motivation factors.



(a) Influence of Age (b) Influence of Experience

Fig. 10. Influence of experience and age with videogames in the feeling of cybersickness.

Finally, as result of the summary questionnaire, our participants enjoyed the experience (M=6.0, SD=1.0) and highly accepted the use of games for CH. Specifically, on average, both *Usefulness* (M=6.5, SD=0.8), and the propensity to recommend to a friend the experience (M=6.7, SD=0.6) were positively rated.

5. CONCLUSION

In this paper we presented a framework to assist the main actors (i.e., domain experts, content experts, pedagogical experts, graphic designers, game developers) that could be involved in designing and developing SGs in Cultural Heritage.

First of all, we would like to emphasize that FRACH, mixing up methodology, design, development, evaluation and test case was effective. In general, focusing only on one of those aspects would have impaired our ability to grasp the overall picture of our endeavor. For example, focusing only on the methodology, would not have allowed us to discover some of the issues, that clearly emerged during the design and development, that were included in the methodological process. Our iterative research approach that conducted our reflections upon methodologies in parallel with the design/development, and the use case (included validation), is a novel, useful, and comprehensive approach by representing a contribution over the state of the art. Therefore, we expect an adoption of our methodology by the community as it is when designing SGs in CH (with eventually enhancements) and an adaptation of it for SGs in other contexts. Secondly, our work was highly heterogeneous and, as pointed out in the literature, we experienced that the team had to carefully employ diverse skills, which implied some efforts in coordination and communication.

We assessed the efficacy of FRACH with a specific case study, named *HippocraticaCivitasGame*, where players were allowed to visit the Thermae of the historical site of San Pietro a Corte and Palazzo Fruscione, and to solve a given puzzle. Results of the evaluation showed that the game was effective in terms of knowledge acquisition and that participants enjoyed it, were highly involved in the immersive experience, and positively rated the idea of using it for educational learning in the field of CH.

Our ongoing works are focused on the evaluation of the other envisioned micro learning goals and on the evaluation of other qualities, such as the functional collaborativeness.

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