Open University of Cyprus

Faculty of Pure and Applied Sciences

Master Thesis
In Information Systems

Development and Evaluation of a 3D Game for the Museum of Marble Crafts of Tinos

Andreas Evagorou

Supervisor
Dr. Panagiotis Zacharias

September 2015

Open University of Cyprus

Faculty of Pure and Applied Sciences

Development and Evaluation of a 3D Game for the Museum of Marble Crafts of Tinos

Andreas Evagorou

Supervisor
Dr. Panagiotis Zacharias

The present master thesis was submitted for the partial fulfillment of requirements for the acquisition of a

Master's degree
In Information Systems

Of the Faculty of Pure and Applied Sciences
of the Open University of Cyprus

September 2015

Summary

Museums and galleries offer a wide variety of learning experiences with a unique contribution; work with real objects that emphasize sensory awareness [30]. In some occasions the enhancement of the interest and engagement of visitors of cultural sites such as museums can be achieved with the use of technology. Such a task can be complicated and difficult to accomplish but if successful could enrich the learning experiences offered by the museum.

The goal of this thesis can be divided in two parts. Firstly, to design and implement a video game that would allow young visitors of a museum to gain new knowledge and show increased interest in that museum and its exhibits by playing the game. Secondly, an evaluation of the game had to be performed to demonstrate if the game was successful to its design goals or not.

The evaluation method used was based on an existing methodology that involved visitors playing the game and completing questionnaires and knowledge tests pre- and post-game. Additionally, museum staff members, after having played the game, should complete their own set of questionnaires and take part in semi-structured interviews.

The findings of this thesis indicate that learning was achieved through the game for all participants. Gender had no effect in the percentage of learning while smaller children performed slightly worse than older ones. Also, the final satisfaction of the players by the game was depending mostly on the initial interest of them for the learning subject and on their motivation to video games. From the completion of this thesis it becomes apparent that learning games in some occasions, like in the case of cultural sites, can provide important assistant in learning and engaging visitors to a certain subject that otherwise would be difficult to get engaged to.

Acknowledgements

The development and evaluation of the game, as well as the completion of this whole thesis would not be possible without the contribution of my supervising professor Dr. Panagioti Zacharia.

The evaluation of the game at the museum facilities was fulfilled with the participation of the Museum, so I would like to express my gratitude for the parties involved.

Finally, I would like to say a special thanks to my special someone, Irene, who helped supporting me and offering me guidance in times of need.

Table of Contents

Chapter 1
Introduction

This thesis had an initial goal of creating an interactive 3D game for a cultural site which would promote a specific exhibit of that site. Having already discovered a museum with the intention of participating in this thesis, the theme was then modified into developing a 3D game that would introduce the visitor to the museum's topic.

In that regard, the basic goal of this thesis was to develop an interactive 3D game that would enrich the museum visitors' experience. This game should allow the museum visitors to gain new knowledge about the topic of the museum and enhance their interest in the museum and its exhibits. Finally the game had to be evaluated as to whether it was entertaining as a game and educational as a learning tool.

Considering that, the main aspects of the research that was conducted in the context of this thesis were the following: determine suitable design frameworks for the game, establish the technology and the means that would allow the implementation of it, and identify appropriate evaluation methodologies for that specific type of game.

1.1 Research

Technology today is affecting every aspect of our lives, not excluding the educational field. From the literature review of this thesis, it will become apparent that technology is vastly used in the educational section, as well as cultural sites, to increase learning and the intent to gain new knowledge.

The technological tools and media now available are raising questions about the relative status of paper-based and technologically enabled productions. Learners and technologies can now be more mobile, building bridges between learning in school and in out-of-school settings such as museums and galleries [55]. Museums and galleries offer a wide variety of learning experiences with a unique contribution; work with real objects that emphasize sensory awareness [30]. Museums represent an invaluable opportunity for cultural and social inclusion, especially for communities that have limited access to cultural and scientific riches [39].

There is an increased awareness about the potential of Serious Games (SGs) for education and training in many disciplines [37]. Allowing the visitor to explore environments, processes or objects and try the knowledge in an interactively way, the visitor is learning from his own immersion in the context of the subject [39].

SGs are a type of games that through playing allow the user to become part of something bigger. The player could be helping solve an existing problem or he/she could gain new knowledge while playing a serious game. Learning games (LGs) are a sub-category of SGs which can be described as educational environments based on a playful approach to learning [26]. Some SGs are thought to provide stealth learning as players are focused not on learning but on playing [48]. James Gee [19, 20] believes that games are enjoyable because of learning since they present just the right amount of challenge, support, and feedback, progressively rewarding mastery with new challenges [54].

Via the findings of the research, it was decided that the answers to the thesis's questions could lie in the development of a LG, which would have the objective of enhancing the experience of the museum visitors, and provide them with the opportunity of gaining new knowledge about the museum, its topic, and its exhibits.

1.1.1 Research Questions

The basic research questions that arose from the scope of this thesis were:

1. Can learning about a museum's topic be achieved for museum visitors of ages 13 to 17 through a video game?

2. Can a video game enrich the experience for museum visitors of ages 13 to 17?

1.1.2 Necessity and Importance of the Research

The expected result covers modern needs of cultural sites in general, for the attraction of new visitors, and may even provide a complementary exhibit by itself.

The importance of this thesis can be divided into four axes:

- Promotion of museum exhibits through the game.
- Acquirement of new knowledge about the museum and its topic.
- Enhancement of the museum visitors' experience.
- Rise of the awareness of peripheral museums in including new technologies.

1.2 Thesis Overview

This thesis goal was to design, implement and evaluate a learning game, with the purpose of teaching younger visitors of the museum of marble crafts of Tinos, about the art of marble crafting. The learning game, named MarbleGames, gave the player the role of a marble crafter who would be moving through various stages of marble crafting, to reveal the game word and win the game.

The design of the game was based on a Serious Game Design Framework [49], and Gagne's Events of Instruction [17] as presented in the design paradigm of Gunter et al [21]. To ensure that the final game would be consistent to these design principles, the game was checked against Gagne's

Events of Instruction at each milestone of the implementation stage. The evaluation of the game was based on a modified version of an existing evaluation methodology of SELEAG [43]. The evaluation methodology of the game used two stages instead of three that the original methodology proposed for reasons that will be explained in detail in the associated chapter. Pre and post-game knowledge tests and questionnaires, as well as interviews were used during the evaluation process.

Analysis and results indicated that the main learning goals of the game were achieved and the research questions of this thesis were answered successfully. Students of the subject group gained new knowledge about marble crafting according to the thesis's findings, and their interest towards the museum and its exhibits was also enhanced by the game and the provided experience.

The rest of the thesis continues as follows: Chapter 2 presents an appropriate literature review, Chapter 3 explains how the game was designed, Chapter 4 describes in detail the implemented game, Chapter 5 depicts the applied evaluation methodology, Chapter 6 presents the analysis and results of the evaluation process, and lastly, Chapter 7 concludes the thesis.

Chapter 2
Literature Review

In the Information Society of today, games can be found in many areas and in many forms. Some of these games are even used to support various causes and often provide solutions to a variety of problems. Designing such a game can prove quite challenging, especially for a novice game designer. The purpose of this Chapter is to reference just a few of the papers that have as a main topic the game development process of SGs. A literature review is thus presented, in which game design frameworks for serious games, user experience studies, various examples of Information and Communications Technology (ICT) apps in museums, as well as a diversity of evaluation methodologies are described briefly. The Chapter's final section discusses some of the deductions that came up from the literature review.

2.1 Serious Game Design

The design and development of a video game can prove quite troublesome and complicated even for experienced designers. In the case of SGs the difficulty of that task increases further more. If we are talking about a novice game designer, then an introduction in the field has to be firstly performed followed by the establishment of certain design principles and guidelines.

2.1.1 Serious Game Design Fundamentals

Game design can be defined as the formal methods for the specification and planning of content and features for video games [21]. The goal of these methods is to maintain intellectual control of the elements of the development process that lead to an immersive and entertaining game [21]. In order to design a SG the designer first needs to understand the basics of video games in general and SGs specifically. In this section, a few references are given that can provide that knowledge.

According to Ferrara [12], a game must have goals and operate under environmental and formal constraints. Video games as a sub-class of games have one extra characteristic: policing of players regarding their compliance to the game rules, as well as the verification of winners and losers are performed by a computing system.

Extending an existing framework [18], Ferrara proposes his own development framework that consists of five levels: motivation, meaningful choices, balance, usability, and aesthetics. Each of these levels contains a short-term and a long-term element. Considering the motives of players, Ferrara notes a few of them, such as: immersion, autonomy, competence, catharsis, accomplishment, social image, and social interaction. Among the guidelines given in the book, is the importance of making a paper prototype followed by an electronic prototype before fully developing the game. That aims to save money, time, and effort. Another important note is that by employing the art of play-testing as much as possible potential problems or inconsistencies can be discovered and corrected.

In a perfect example of a self-teaching tutorial about serious game design [49] there is an introduction of key concepts, steps and processes involved in designing a SG for learning. It was created in the context of being used in a classroom, thus it uses examples and exercises to display its guidelines. A number of questions were asked to be answered by a group, using the brainstorming method, thus helping them learn how to develop a successful SG. Under consideration were taken both gaming and instructional implications for each decision taken during the tutorial, and of course the development process presented.

2.1.2 Serious Game Design Frameworks

Laurel [32] and Santos [46] explained that the designer of an educational game needs to be a super designer with the skills of an engineer, an artist, and a psychologist, with the knowledge of

teaching. To help ease that burden to aspirant SG designers, some existing design frameworks are presented.

An interesting research project had the aim of developing technologies and methodologies in order to promote learning from museum collections [39]. The research project in discussion is an exploratory study about the use of game engines, on the development of educational games for use in museums. A presentation of different views about the educational function of museums is provided, along with examples of digital technologies used in museums.

According to Nobre et al [39], a concept of paramount importance in order to facilitate the educational objective of museums is the handling, which implies physical action on the exhibition, a note that is commonly found in most similar projects. Interaction, immersion and navigation are the aspects that allow virtual reality (VR) to create a sensation of reality [39]. By using VR in museums, visitors learn from their own immersion in the context of the subject.

An identification of the most appropriate techniques and methodologies for the construction and efficiency testing of VR educational games, as constructed by the authors is given here. The definition of this design methodology includes 1) new concepts in software engineering that include interdisciplinary aspects applicable to such environments, 2) different learning literature, 3) free software alternatives, 4) a modular architecture of design for the environments and objects providing its reuse and standardization at all levels, and 5) the multiplayer ability of the games as a proposal for collaborative learning [39].

In a project of Serious Games – Engaging Training Solutions (SG-ETS) [10] it is described how it aims to produce a minimum of three SG prototypes that will address a learning need or learning outcome that will help solve a priority business problem or fulfill a specific training need.

The aim of the research summarized in that project is to describe a framework and a development process that help ensure that a serious game satisfies the needs of the target learner group. The SG-ETS's project aims to answer various key questions about the game design process, of which the authors focus on the question "What are the characteristics of people that are relevant to the use of games for learning?".

An existing framework [11] was taken and modified to present a new one, with the main difference being the approach taken in the learner specification part. After reviewing various

methods of the learner dimension for game-based learning, De Freitas and Jarvis [10] decided to develop a multi-faceted approach to defining learner groups including self-assessment surveys, workshop activities and semi-structured follow-up interviews with targeted learner groups, and other proven analysis methods.

A user study about an infection control in acute healthcare is then given, and the effect of the implementation of a SG is discussed as to whether it would help train the nurses. It is noted that due to the age variance between the nurses, it would be wiser to use a mobile game instead of a PC game, while it is also said that role-play and peer to peer teaching in some cases proved more preferable for the nurses than other methods of teaching.

Design, Play and Experience Framework [54] focuses on four elements of serious game design: learning, storytelling, gameplay, and user experience. The heart of SG design is described as the ideal overlap between pedagogical theory, subject matter content, and game design [54].

Six essential components of the formal conceptual structure underlying a SG according to a SG design assessment framework [36] are:

- Purpose
- Content
- Fiction and narrative
- Mechanics
- Aesthetics and graphics
- Framing

Four important aspects of a SG are listed in a four-dimensional framework [11]. These are: Context, learner specification, representation, and pedagogical model or approach used. An important contextual factor would be the location of the game. Learner specification should take into account the aspects, preferences and particulars of the learner group. Representation is mostly about the levels of immersion, fidelity and interactivity of the game. Pedagogical model, as expected, are the teaching methods and approaches used by the game to assist learning.

Deciding on which educational or instructional theories to follow is complicated [21]. The basic approaches to learning according to a formal design paradigm for serious games [21] are: acquisition of literacy, meta-learning principles like basic numeric manipulation, science, social interaction, information mining, and communication [21].

Three theories that appear to be most closely aligned with generally accepted game design principles according to the same design paradigm [21] are: Keller's ARCS Model [29], Gagne's Events of Instruction [17], and Bloom's Taxonomy [05].

Through his research Gagne developed three principles that he considered essential for successful instruction [21]:

1. Provide instructions on the component tasks that lead to the final goal
2. Ensure that each component task is mastered
3. Sequence the component tasks to ensure optimal transfer to the final goal

Gagne [17] believes that there are nine events that are required for learning to occur:

1. Gain the learners attention
2. Inform the learners of the objectives
3. Stimulate recall of prior learning
4. Present stimulus or lesson
5. Provide learning guidance and instruction
6. Elicit performance
7. Provide feedback
8. Assess performance
9. Enhance retention and transfer

Bloom [05] classified learning in three domains: cognitive (intellectual level), affective (emotions, interests, attitude, attention, and awareness), and psychomotor (motor skills and physical abilities).

Within the cognitive domain, Bloom identified six levels that can be used to acquire knowledge about a topic [21]. The levels move from simple to complex and are designed to increase comprehension [21]. These levers are referred to as Bloom's Taxonomy:

Knowledge

Learner can recall information.

Comprehension

Learner can explain and predict.

Application

Learner can solve problems and use information.

Analysis

Learner can see patterns or concepts and organizational structure may be understood.

Synthesis

Learner can build a structure, put parts together to form a whole, with emphasis on creating a new meaning or structure.

Evaluation

Learner can compare and make judgments about the value of ideas or materials

According to Bloom [05], all students can learn a subject given sufficient time and motivation. The critical ingredient is changing instructional methods so students can master the content [21].

Motivation is a necessary but insufficient condition needed to ensure that learners actually learn something [21]. Keller's ARCS Model relies on four foundational categories that are to be applied when designing instructional activities: Attention, Relevance, Confidence\Challenge, and Satisfaction\Success [21]. Dempsey and Johnson [09] proposed a rubric when applying the ARCS Model for selecting and analyzing games [21].

2.2 User Experience Studies

An interesting study performed by the International Usability Partners (IUP) [33], analyzes cultural differences and similarities in gesture-based operation of multi-touch interfaces. The study begins by displaying how different countries give different meanings in some gestures, and wonders if cultural differences also exist for gestures used to operate a multi-touch interface.

The aim of the study was to help designers design multi-touch interfaces, with the created gesture set recommending one gesture for each investigated action. Their main objectives are to reveal differences and similarities in the use of multi-touch interfaces, help designers understand how users expect to interact with interfaces, and strengthen the international network of usability partners.

340 participants from 9 countries took part in this study that collected and analyzed 9520 (28 actions) gestures coming to the following conclusions: 1) There are no cultural differences in using gestures to operate multi-touch interfaces with one exception: the Chinese used significantly more symbolic gestures than users from any other country (possible explanation: unique script in

China). 2) Differences in some gestures were found because of the different experiences with gesture-based touch screens. 3) Only few differences could be found between experienced and novice users.

An attempt was made in order to explore the interactions between users of different age groups around a multi-touch table, and investigate whether the spatial factor affects their behavior [40]. The aim of that specific study was to identify implications in developing engaging and usable applications that enrich the overall user experience. The method used to perform this rapid ethnography was an 'in-the-wild' approach.

The study took place on the visitor information center in Kirkstall Abbey, in Leeds, UK, over a 12-day period, where a Microsoft Surface 1.0 SPI was used to present a collection of historical images of the Abbey. The table was placed in a room used for children activities, and it was placed at the far side of the room next to two exhibits, with little space around the Surface but chairs could provide some kind of comfort and encouragement for people. The application used was designed to support group interactions with a set of multi-touch gestures commonly used on interactive surfaces such as dragging, rotating, etc.

Observations of the study followed the main principles of ethnography as described by Blomberg et al [04]. The use of a video recording was described as unnecessary by the authors so they collected information via an observant. Also, opportunistic interviews and informal discussions were conducted with a representative sample of visitors. Six different types of visitors were identified, which included from people who successfully interacted with the application to people who did not even notice the table at all.

The authors indicate that through their findings, most of the visitors saw the application positively and engaging, with educational and informative integrations. An interesting finding was also that the use of the table made most visitors that interacted with it not interested in the other visual signs or exhibits of the room. The main influential characteristic of the table was its physical appearance, while on the other hand many visitors were probably discouraged by the children-friendly nature of the room. Also, unknown technology or latency times seemed to affect visitors' decisions on interacting with the table. The honey-pot effect worked with positive or negative effects on whether the visitors would notice the table (The honey-pot effect refers to a crowd of people who gathers around a display attracting the attention of others and making it much more likely that they will also notice and approach the technology [40]). The multi-touch surface

enabled collaboration between the users, while interruptions were most of the time perceived as "part of the game".

Some novel findings according to the authors were that their finding contradicted with Ryall's et al [44] findings, who suggested that "Users do not view an interactive tabletop as a computer", and the fact that sound could be used to give clues to the visitors about the use of the application.

The authors provide their design implications through their findings, where they support that various stimuli in the room, as well as the nature of the room itself can influence the walking path that people will follow. Physical appearance attracts attention while a particularly hard obstacle for users to overcome was found to be their reservation towards technology. Interactive displays should be kept simple according to the authors, with sound playing an important role to the user's experience, and the application providing a freedom of interruptions. Lastly, the interactivity or lack of it should be obvious to the user, again according to Patsoule [40].

2.3 ICT Apps in Museums

One of the goals of museums today is to promote rapprochement and public understanding of science and technology through activities and informal educational experiences supported by interactive, experimental and playful approaches [45]. In this section a set of projects and studies created with that specific aim in mind are reviewed.

2.3.1 Trail Generating Apps

A web-based museum trail generating project for university-level design students [41] aims to help design students use and understand museum collections, and explore ways of using mobile learning technologies to enhance learning.

The I-Guides system was chosen for the project to create twenty trails that were hosted on a website, available to the users via a wireless-connected to the internet PDA. The trails were intended to supplement and not replace other coursework of the students, while they aimed to encourage generic skills. In the trail design, social elements were included that continually prompted students to articulate their responses. Additionally, collaboration was also included in the design, in the form of interviews with contributors and joined revisions of trail design.

The evaluation methodology used for this project was a cyclical approach [27] that was consisted of a front-end, a formative, and a summative stage. Results were taken by observing students dialogues, activities in context, interviews and uploaded data. The physical space appeared to have made a prominent impression to the students. Among the findings of the project, was the fact that the trails did point students to objects that they would not otherwise have noticed. Through student feedback, it was showed that the trails enhanced the students' knowledge, interest and closeness to the objects. The time spent at the exhibits when following trails exceeded the normal. By using the trails, the students moved much slower through the museum exhibits, paying more attention and focusing on each key object, while in some occasions they were prompted to look at objects in different ways.

While as noted by the authors some problems existed, most of them caused by the chosen PDA, and the distraction it sometimes caused, the students responded positively to the trails content and structure. Students appreciated the additional information about the exhibits, while in the cases of students of early years of study the trails helped them feel less overwhelmed by the museum.

A model for tangible user interfaces that focuses mainly on the user experience during interaction [50] has the concept of the exploration of the possibility to enhance the access to information using tangible interfaces. A model proposal is given with the design concepts and heuristics grouped into the following four themes: 1) Physical and digital representations; 2) Actions and effects; 3) Exploration and collaboration; and 4) Engagement and fun. These concepts relate to concepts presented by Hornecker and Buur [23], Sharlin et al. [47] and Antle [02].

To make an interface more suitable for children, since as it is claimed, younger children, and especially children under the age of 7, have difficulties to relate physical manipulatives to other forms of representation, it is recommended to exploit perceptual mappings. The design needs to be based on an understanding of how and why children's actions in space relate to changes in cognitive and motoric development [50].

The application created is used to determine a route through the museum exhibition, based on the interests of the visitors. The goal is to give children guidance and optimize their museum-going experience. By enabling trial and error activity and lightweight interaction, the experience is expected to be more engaging and encourage exploration. Collaboration is facilitated by multiple

access points, non-fragmented visibility and space for friends like Antle [02] calls it. Animation is meant to be engaging and motivating.

The authors conclude that their main screen enabled trial and error activity and facilitated exploration and collaboration. Actions and effects appeared to be tightly related. There were indications of engaging animation and motivation by the children to achieve a high score. The only one of the four themes of design that was deemed irrelevant in the end was the first one, since no tangible, physical objects were included in the project.

2.3.2 Learning Apps in Museums

I-Guides [24] is an information technology research project which is used in museums with the aim to enable visitors to intentionally capture one's museum experiences for later reflection and investigation of personally relevant science ideas via the web. From the perspective of the museum educator, I-Guides can be used to support educators in making effective uses of exhibits and exhibit-based content for inquiry-based teaching.

By redesigning her previous project, Electronic Guidebook [25], Hsi removed bulky technology from the hands of the visitors, replacing it with an easily carried or wearable item, such as a card or a yo-yo that contained an RFID chip to help capture a photo. After the museum visit, the visitor could enter the website to review his or her photos or additional material. An application was also developed for the educators which allowed them to contribute to the visitor's engagement and ease their own workload, with advancements like remotely controlling a larger exhibit, or sending additional information via e-mail to a visitor.

One of the findings of the project was that the item that was handed to the visitor should be lightweight, waterproof, drop-proof, and inexpensive, without interfering with the exhibit interaction.

Myartspace [52] is a service on mobile phones for inquiry-led learning that allows students to gather information during a school field trip, which is automatically sent and thus accessible at any time for viewing, sharing or presenting through a website. Through their research Vavoula et al. [52] discovered that certain aspects could improve museum learning. Examples of that include a pre-visit preparation, post-visit activities, as well as technology enhancements during the learning stages.

The evaluation of Myartspace was based on the Lifecycle approach [35], using the M3 evaluation framework [51]. M3 comprises of three levels which are used to evaluate from individual activities of users to the longer term impact of new technology. The development of Myartspace comprised of four broad phases that were compatible with an Agile Development approach [03].

In the discussion section of Myartspace [52] the most important aspects of the project are presented. Firstly, it is noted that it is time and cost consuming for the school and the museum respectively to use Myartspace despite the good results it provides. The website was not intuitive in its use. The use of mobile phones was the main attraction of Myartspace but it is also explained that in order to keep their attractiveness they should be replaced with newer models every 18 months or so. Despite some other minor difficulties, the authors finally conclude that their project can successfully bridge the museum-classroom gap, enable students to create artifacts and work on them whenever they please. Also students were found to be appreciative of the use of modern technology, and enjoyed the experience that provided motivation for them.

Similar to Myartspace, the MuseumScouts project [55] aims to develop learner-centered approaches in the museum environment, with its focus being on knowledge acquisition, transformation and communication. Despite just using mobile phones, in MuseumScouts, a range of devices could be used, to gather information in the form of notes and photographs. By working in teams, the students then created interactive web presentations and quizzes to inform their peers.

Just like Myartspace, MuseumScouts suffered from time and cost efficiencies and other similar problems like internet availability. The findings presented show that learners in order to successfully benefit from the MuseumScouts experience had to possess a variety of skills, like taking responsibilities or using an authoring tool, while it was also observed that development of these kind of skills and competences could be achieved throughout the project. Also, students seemed to be encouraged to take more responsibility for their work than usual, and in addition they became more accustomed to asking questions for learning. Furthermore, students seemed to acquire and extend their ICT skills.

In the discussion section of MuseumScouts [55], it was noted that students appreciated mostly the museum visit; they were motivated by their involvement in the project, while an enhanced subject understanding was demonstrated in a number of occurrences. Also, the peer to peer teaching was found to be very important in the whole learning process.

2.3.3 Learning Games in Museums

A system for supporting children's learning in museums using two PDAs is presented here. Mugender [56], as it is called, provides children with opportunities to answer questions related to exhibitions. Mugender is based on an orienteering game and it is played by a pair of users.

When a user visits an exhibit in the museum (which is RFID tagged), a question appears regarding that specific exhibit, in an attempt to engage him/her in a deeper understanding of that exhibit. Communication and collaboration is expected to be achieved by visually displaying the status of the paired partners on the PDAs in real time. Also, a website that reflects the users' results and answers is provided after the museum visit.

There are a total of 12 questions, which when answered unlock a final question, revealing at the same time a photograph as a hint. The photograph is hidden behind 12 panels, with each panel revealing that part of the photograph only if its corresponding question was answered correctly. This is meant to motivate the players in answering correctly as many questions as possible. To the users a transceiver is also handed in order to cooperatively answer a question while consulting with each other if they please.

After evaluating the system, the authors presented the following results: Mugender enabled users to view exhibits interactively whilst presenting opportunities that caused the users to look at the exhibits. The children appeared to be highly engaged with exhibits that had poor interactivity. Motivation drove children to actively work on the questions. No children were confused about the system, and in addition, the website was checked by the users even at home in some cases. Collaboration, communication, awareness and peer to peer assistance were some of the characteristics of the interactions between users that the created system. On the downside, some children did not pay attention to the exhibit after answering the related question, while some problems with the equipment or the users' ability to use them were discovered. It is also worth noting that in this project it might be profitable to get the museum experts involved with the whole process.

Kurio [53] is a museum guide for families. A discussion of three design strategies (embodied interaction, game-learning, and hybrid systems) for improving the quality of social interaction and learning with interactive museum guides is provided in that paper. Using these strategies, Kurio was developed with the aim of supporting family visits in museums. Again, a game-learning

approach was used to motivate and structure a family visit. As a basis for the interaction structure, the learning Cycle was used [16], while Bloom's taxonomy [05] was used as the learning model.

By trying to repair a broken imaginary time-map, the family in the role of time travelers must complete a series of challenges that collect information from the museum. The missions were topically organized and directed families to particular parts of the museum. Three missions had to be executed successfully to fix the map, with each family member getting a mission assigned to them concurrently to allow collaboration, while one member acted as a coordinator using the PDA application. Three independent tangibles (listener, pointer, and reader), a PDA and a tabletop display were used in this context. The tangibles were used as the means for collecting information from the exhibits, the PDA was used to coordinate and support the family member, and the tabletop was used to provide awareness of the game state to the family.

The game length had an average of 45 minutes, and was preceded by a short tutorial on the system and brief interview and questionnaire on previous experiences. After the game another interview and questionnaire followed, while 2-4 weeks later volunteering families conducted another interview to provide more results. Two questionnaires were created, one for children 7-12 years old and one for children older than 13 and adults. Video and audio recordings were gathered from this process.

Analysis showed that the overall impressions were positive. Observations also showed that families momentarily ignored the technology and collaboratively reflected on the challenge and the exhibits, while in some cases there were coordination issues that overwhelmed the family members. Many commented that the components were fun and improved the experience, while others would prefer a different application with fewer tangible devices. Kurio was described by the users as engaging and fun. Also, the authors concluded that the initial goals of social interaction and learning were achieved.

Another learning activity in a museum for small groups can be found in an activity based on a "Mystery in the museum" story that allows collaboration through mobile devices [06]. The aim of the activity was to augment interaction with the museum through the game which included various puzzles related to exhibits. Rewards were given through the game in the form of clues that helped the players solve the mystery. There was also the intention of creating competition between the different groups of players. Each group receives different pieces of information, so in the end they have to collaborate to solve the mystery. A pre-visit session of the students with their

teacher about the subject of the exhibits is recommended. Also, the actions of the visitors during the visit are stored in the server for a post-visit evaluation.

Two puzzles need to be solved during the game: the text game and the image game. In the text game, the players get different verses of a subset of verses and need to compose correctly a manuscript from the exhibit to win the game. In the image game, they get different parts of different images and they need to exchange pieces in order to have all the parts of a chosen image. When the image is complete they need to find the item in the museum that is the solution for their puzzle.

During the experiment at least one evaluator observed the behavior of the students, while at the same time playing the role of the museum guide and also explaining to the students how to use the application. Results showed that students first engaged in exploring the interface of the games, with the PDAs drawing most of the children's attention. Two profiles were used in the game experiment with different interesting results. Also, the strategies that the team adopted differed from team to team. A downside noted by the authors was that the students paid attention only to the exhibits relevant to the puzzles and ignored all the rest, while in some cases evidence showed that the puzzles were too difficult for that specific age group of the students that were included in the experiment.

In a quite relevant case, the Mystery at a museum [31] game for museum education is presented briefly here. This game was designed to be played synchronously by groups of parents and children over a two to three hour period. Primary goals once again were the engagement of the visitors in and across the museum exhibits and the encouragement of collaboration between them.

The game had the team posing as a group of experts (technologist, biologist, and detective) in order to solve a crime of theft of a valuable object of the museum that was replaced by a replica. Each of the expert roles had different capabilities to assist in team members' collaboration. Players were organized as six players (three pairs) per team, where each pair used one pocket PC and one walkie-talkie. Players had various ways of collecting clues, including interviews with virtual characters, collecting virtual clues and virtual tools to analyze them. Dynamic virtual characters and objects could appear in a room for the players to interact with, depending on the player's role. The game would be completed when players had enough evidence to obtain a virtual warrant for the arrest of the culprits, with one of the organizers playing the role of the judge.

A brief tutorial of the game mechanics was provided to the visitors before starting the game. At the end of the game players discussed the process and completed surveys to help the collection of data. Interviews were taken from a sample of the players. Results showed that the combination of depth and breadth provided by the game was engaging and effective in encouraging visitors to think about the exhibits [31]. The roles were found to be extremely effective in engaging the participants in collaboration to solve the mystery. The game even provided advanced parent child interactions that were surprising to some of the visitors.

2.4 Serious Game Evaluation

Evaluation is one of the most important stages in game development. Through this stage the main problems and bugs of a game can be identified and fixed leading to the completion of the final game. Vavoula et al. [52] notes that it is through continuous evaluation and fine-tuning of the new technology with the learning practice, that an educational innovation will reach its full potential in transforming educational practice.

The evaluation methodology that was used in this thesis was a modified version of the one applied in the SELEAG project [43]. The aim of that project was to evaluate the game "Time Mesh" and it was consisted of three stages. The first stage was called Alpha testing and it was performed by members of the development team unassociated with the development of that part of the game. The aim of the first stage was basically to identify any problems and assess if the game was motivating and successful to its expected learning outcomes. The second stage (Beta) was performed by the teachers of the target group, which were students of various schools, and its focus was on the game play, the mechanics and the interaction with the game. The data collection tools used in this stage was a questionnaire and a semi-structured interview. The third and final stage (Gamma) was performed with the end-users, during the first round of implementations. This stage's aim was to assess knowledge acquisition by the game and it was consisted of two knowledge tests and two questionnaires by the students as well as one questionnaire by the teachers.

Another interesting evaluation framework is the Serious Game Assessment Framework (SGDA) [36]. SGDA Framework attempts to offer a structure to study the formal conceptual design of SGs in relation to their explicit and implicit purposes. A questionnaire that de- and re-composes several design elements through the studies of two SGs focused on social change was used for that

purpose. A set of quality indicators that can help a conception team to evaluate the quality of their learning game during the design process [26], is given by Iza Marfisi-Schottman et al [26]. These quality indicators were structured in six facets: Pedagogical Objectives, Interactions, Problems and Progression, Decorum, Conditions of Use, and Estimated Cost.

In the evaluation of the Icura user study [37], it is noted that the most common approach to analyze the effectiveness of SGs is a simple test after the game session or the comparison of pre and post test results to measure learning effects. The latter approach is the one used in that case. One important comment noted is that if the pre and post-tests comprise of the same questions, it is possible that the player may remember those questions and, wittingly or unwittingly, pay more attention to find the correct answers during gameplay [15]. To compensate that, the authors of [37] used different questions for the pre and post-test, which was useful to completely exclude the bias [37], but had the side-effect of losing the chance of directly comparing the correct answers from the pre- and post-tests. The evaluation was performed with the use of a pre-questionnaire collecting demographic data and user proficiency with computer games, a pre-test assessing the starting knowledge about Japanese culture, the post-test to assess improvement of knowledge, and a post-questionnaire to assess the satisfaction of the player [37]. Another post-test after six months was used as a medium-term analysis of retention.

Another example of an evaluation method that uses pre and post-questionnaires was the evaluation of a technology enhanced learning game [07]. From that paper it is also worth noticing that the players felt frustrated by their inability to win the game, which suggests that the difficulty of the game impeded important learning [07].

2.5 Literature Review Deductions

After studying the above mentioned papers, a few similarities between them become very apparent, and could be used to form guiding lines to follow when designing and developing a similar educational game.

Firstly, the target group of the game should be small groups of students or families with children, since that appears to be the most common type of museum visitors.

Tangible devices should be reduced to the minimum, just like Hsi [24] suggests, while remaining completely simple in use. This would allow visitors to pay more attention to the exhibits and avoid the trap of being too focused in the technology or a specific device. It would also remove the fear of being overwhelmed by the technology for users with minimum experience. Additionally, the use of any application should be engaging but at the same time as simple as possible, just like Patsoule [40] states.

In other regards, it was noticed that almost all of the games and experiments included pre-visit educational session and in some cases post-visit sessions either through classroom or via a website. Furthermore, it was apparent that in the projects that included some kind of peer to peer teaching, it was easier for the students to get more engaged to the learning process while they also seemed to enjoy it more. Also, it is proven that when teaching something enables the one teaching it to grasp a better understanding of the subject itself. It is worth mentioning that as it is clear from the findings of Klopfer, E., et al [31], the assigning of different roles could enhance collaboration within a group.

Use of inquiry-based methods for engaging and motivating visitors was used in some occasions. Also, physical appearances and spatial factors are always prominent in designing a game. Another important guideline would be that a designer should have the knowledge that is related to the specific museum, theme, or exhibit, before attempting to create a game or an application about that specific theme. Furthermore, the designer should always have the support and guidance of an expert on that specific field, like a museum operator or a teacher, just like Nobre et al [39] suggests.

Additionally, in the evaluation process the most common way of collecting data was with the use of short interviews and questionnaires, when in certain cases the evaluation process would be performed after weeks to better estimate the gained new knowledge of the visitors. An example of an approach like that can be seen in Kurio [53]. Also, video and audio recordings where usually used to observe the surveys.

One final note would be to make a game-based learning experience as motivating and engaging to the exhibits as possible, while at the same time trying to keep the main focus of the visitor to the museum exhibits and not just on the game itself.

Chapter 3
Methodology

Having researched and reviewed the relative literature, the concept of the game to be designed begun to take form. The type of the game was determined, the learning goals were established, and the design framework was specified and applied. This Chapter displays the information relative to these regards and concludes with some issues that emerged during the design process of the game.

3.1 Game Type

It should be clear by now that an interactive 3D game was the initial intention of this thesis. That game should provide the opportunity to the player to gain new knowledge that goes beyond the game story and its mechanics. The type of game that could teach its player about a specific topic had to be determined.

3.1.1 Serious Games and Learning Games

Increasingly, evidence in the literature is indicating that Information and communications technology (ICT) based simulations and more recently games are accelerating learning, increasing

motivation and supporting the development of higher order cognitive thinking skills [10]. Learning games are a sub-category of Serious Games that use game mechanics for educational purposes [26, 01].

With the concept of making learning easier and engaging, the design and implementation of a learning game was decided. The main goal of this learning game was to engage visitors in learning about a specific topic and interest them in the exhibits of the museum. As it was almost impossible to develop a game that would allow a visitor to learn every piece of information that the museum provides, a selection of the most important aspects had to be made in order to be learned through the designed game.

3.1.2 Game Genre

Some of the articles that were reviewed earlier in the literature review Chapter, presented games that contained puzzles and inquiry based games. One of them [56], revealed parts of a hidden image with each correct answer provided. Reviewing these aspects as well as researching online game genres that usually cause engagement, it was decided that the designed game would be divided in different sub-games with various genres. The whole game would then be comprised of puzzle games, a memory game, a quiz-based game, and a tabbing game. The idea of the main game would be to reveal the game word in a manner similar to revealing the hidden image of Mugender [56].

3.2 Learning Goals

The main goals of the game that was designed and implemented in this thesis were two. The first one was to help the younger visitors of the museum of Marble Crafts of Tinos achieve new knowledge through the game regarding the topic of the museum. The second was to help the same visitors become more interested and engaged to the museum and its exhibits.

3.2.1 The Museum of Marble Crafts of Tinos

The museum of marble crafts of Tinos is a modern peripheral museum that displays a variety of artifacts and exhibits associated with the art of marble crafting. It allows its visitor to learn about all the stages of the marble crafting process, the most common used tools for those stages, the

most known Greek marbles, as well as the most known locations and artists involved with marble crafting.

3.2.2 Marble Crafting

Marble crafting is the art that begins from the process of excavating the marble from the ground and ends with the crafted artifact placed in its final attraction site. The usual stages of marble crafting in order of execution are: extraction, transport, sketching, carving, installation.

3.2.3 Expected Gained Knowledge

After consulting with the museum experts, an agreement was reached as to what the expected gained knowledge from the game should be.

The visitors should gain by just playing the game the following:

- An understanding of what marble crafting is
- Knowledge about the most important stages of marble crafting
- Knowledge about the most known tools of various stages of marble crafting
- Information about marbles in general (such as, how they are made)
- Knowledge about the most common extraction techniques
- Knowledge about the carving technique
- Knowledge about installation and assembly of marble crafts

3.3 Designing the Game

The game designer and artist Mary Flanagan [14] argues that "serious games are among the most challenging games to design" as they try to be enjoyable and effective at the same time [36]. Taking that note into account and having a specific goal at hand, the following step was to design the game. In designing the game of this thesis, guidelines and instructions from the Serious Game Design Tutorial [49] and Gunter's et al [21] design paradigm were followed.

3.3.1 Design Elements

According to the Serious Game Design Tutorial [49], to design a game you must first identify the following elements:

1. Requirements
2. Learning objectives
3. Game Story
4. Teaching methods
5. Gameplay
6. Game mechanics

3.3.1.1 Requirements

Functional requirements define the functions of the game and its components. The functional requirements of the game are shown in table 3.1.

ID	Description	Priority
	Gameplay	
FR1	The final goal of the game is presented early in the game	High
FR2	The goals of the game are clear throughout the game	High
FR3	The game should have a gameplay duration of about 20 minutes	High
FR4	As the game progresses new knowledge is revealed to the player	High
FR5	The player can deviate from the goals of the game to access extra information and knowledge base	High
FR6	The consequences of the player actions can be clearly seen in the game environment	High
FR7	The player must go through one game before he/she can play the next	Medium
FR8	There are five sub-games in the game	Medium
FR9	There are five information rooms in the game	Medium
FR10	Sub-games and information rooms are unlocked with each pass of a sub-game	Medium
FR11	Information rooms are available to the player throughout the main game after they are unlocked once	High
FR12	Sub-games are available to the player for a replay throughout the main	High

	game after they are unlocked once	
FR13	The game is available in Greek and English versions	Medium
Game Story		
FR14	Game story is clear to the player from the start	High
FR15	The results of the players actions are fair	High
FR16	Reward is given to the player for every successful action	High
Mechanics and Usability		
FR18	Visual and sound effects let the player know of his action's or the consequence of his action's execution	High
FR19	Game graphics allow the player to know what to do next in the game	High
FR20	The player is informed of his progression in the game throughout the game	High
FR21	The player can easily get in and out of the game	High
FR22	Controls are consistent throughout the game	High
FR23	Game colors are consistent throughout the game	Medium
FR24	Fonts and dialogues are consistent throughout the game	Medium
FR25	Game menu is easily accessible at any time	High
FR26	Starting the game the player has enough information to start playing the game	High
FR27	In some cases help is provided to the players to help solve the puzzle	Medium
FR28	There is enough feedback to let the player know what he did wrong and fix it the second time around	Low

Table 3.1: Functional requirements of the game.

Non-functional requirements are the requirements that specify criteria that can be used to judge the operation of the game. The non-functional requirements of the game are shown here.

Target Group

The core museum going contingent are families – specifically late elementary through middle school aged students [31], and that is why the target group of the game was chosen to contain children of middle school to high school. After consulting with museum experts, the appropriate age group of our target group was decided to be children of 13 to 17 years old. The game should be however as engaging and educational for all ages older than 10 years old.

Compatibility

The game should be available for various consoles. That would assist the museum in installing the game wherever it suits the museum the most as well as allow the museum to relocate the game's position and alter its appearance at any time.

Accessibility

The game should be available for play for anyone in the museum. For this reason there was no need to provide increased accessibility online.

Performance

The performance of the game should be high enough to let the player enjoy the game and not low enough to reduce the player's enjoyment and learning. The game should last about 15-20 minutes to allow other visitors of the museum have a try.

Usability

The game should be easy to use and understand while at the same time it should provide some challenge to the player.

3.3.1.2 Learning Objectives

Learning objectives should be SMART: Specific, Measurable, Attainable for target audience, Relevant, and Targeted to the learner [49]. In an effort to conform to these guidelines, the learning objectives of the designed game were created.

Various stages of marble crafting exist with each stage containing many information and different tools to be learned. In order for the players of the game to tell the difference between those stages more clearly by just playing the game once, it was decided to divide the game in smaller sub-games.

Sub-Games

Taking into consideration the museum experts opinions, the following knowledge should be gained by playing each room of the game.

The first sub-game was the only one that was not a part of a stage of marble crafting. This game was chosen to educate the player about the mineralogical composition of the marbles, so from this game the expected gained knowledge was to:

- Learn the most common elements that marbles are consisted of.

The second sub-game was relevant with the marble extraction stage of marble crafting. From this game the expected gained knowledge was to:

- Learn about some of the most common marble extraction techniques.
- Learn about some of the tools used during the marble extraction techniques.

The third sub-game was relevant with the sketching stage of marble crafting. From this game the expected gained knowledge was to:

- Learn that sketching is important in order for the marble crafter to proceed to the carving of the marble.

The fourth sub-game was relevant with the carving stage of marble crafting. From this game the expected gained knowledge was to:

- Learn about the process of marble carving.
- Learn about some of the most common used tools of this stage.

The fifth sub-game was relevant with the installation and assembly stage of marble crafting. From this game the expected gained knowledge was to:

- Learn that big marble artifacts are usually made of smaller pieces, and an assembly process is usually executed during the installation of the completed item.

Information Rooms

From the five information rooms, the player should have the opportunity to gain extra knowledge, if interested, in the following:

- Various Greek marbles.
- Marble crafting tools.
- Marble crafting sketches.
- Museum exhibits.
- Marble relevant sights of Greece.

3.3.1.3 Game Story

Sometimes, complex game stories increase extraneous load [49]. In order to avoid that and since a basic linear story was sufficient for a small game such as the one designed here, the game story chosen was a very simple while meaningful one, relevant to the game's learning goals.

Character

The character was a nameless marble crafter who had to complete some of the stages of marble crafting. Of course, that role was given to the player as he/she entered the game.

World

The world of the game was the island of Tinos, in which the player as the game character mentioned above, would travel from one location (sub-game) to another until he/she would unlock all five sub-games of the game. By winning all sub-games the game word would be revealed and the main game would then be won.

3.3.1.4 Teaching Methods

Creating an instructional game involves many decisions about what to teach, when and how to teach it [49]. The teaching methods that were decided to be used for this game were the use of scaffolding and feedback.

Instructional Sequencing

The game was linear and straight forward. Instructions and guidelines were given to the player at all times to help him/her understand what he/she was supposed to do next. By following the instructions and obeying the rules of the game, the player could succeed and win the game.

Scaffolding

During the game, many instructions were given to the player to let him/her understand how the game was to be played. At some points, help buttons were provided to assist the player in times of confusion. These help elements would not at any point provide the answer or a way to find the answer. This was decided in order to make sure that the player would have the chance to learn

the subject he/she was supposed to learn. Help elements were available only for certain challenging stages of the game.

Feedback

Feedback was used to encourage reflection and let the player know at each point of the game what the current status of the game was. During the game, if the player made a mistake, feedback would highlight to him/her that mistake so that he/she would be more careful on the next round. If the player succeeded positive feedback would be displayed to him/her.

3.3.1.5 Gameplay

Games are all about interactions [49]. The interactions of the game had to be helpful to the learning objectives of the game and not distracting to the player.

Interactions

The player throughout the game had to interact with game objects, the User Interface, and if he/she wished, could also collaborate with other visitors of the museum. With every action of the player, a consequence was displayed, either positive or negative.

Gaming Elements

The player in order to win the game had to complete the word of the game, which was consisted of five letters. With each win of a sub-game, a letter of the game word was revealed, so in order to win the game the player had to win all five sub-games. By just playing a sub-game, regardless of winning or losing, the next sub-game and the corresponding information room would be unlocked and become available to the player.

There were two ways for the player to lose in a sub-game. The first one was if the game was time limited, the player would lose only if the time was expired. If the game was question oriented, the player would lose if he/she made three mistakes as he/she was given three lives from the start. In case of losing, the player had no extra consequence to the rest of the game as he was free to replay the sub-game and win it. There was no other mention to the main game if games were lost other than the sub-game icon's color (gray) and the unrevealed letter of the game word. So the player

could play as much as he/she wanted to win the game without the possibility of losing since there was no game over situation in the main game.

Throughout the game, the sub-games were quite different, so there was not an increased difficulty as the player progressed in the game, just a different sub-game available to him\her. This difference in the sub-games would also assist in retaining the player's attention, since by exposing various types of games to him/her it would be less possible for the player to get bored during the game.

3.3.1.6 Game Mechanics

Instruction used a set of instructional techniques to deliver information, provide learning activities, build desired mental models, and assess performance [49]. The mechanics or else formal rules of the game are explained in this section for the main game and each sub-game.

Game Mechanics
Main Game
There was no game over situation in the main game. The game was won if the game word was fully revealed. The player could unlock a sub-game and an information room only by playing its previous in line sub-game. Starting the game, the first sub-game was the only one unlocked in the game. The only way for a letter of the game word to be revealed was to win the corresponding sub-game of that letter. For example, by winning the first sub-game the first letter of the game word was revealed, and so on. The unlocked sub-games and information rooms could be accessed throughout the main game. Interaction and guidance was achieved with the use of dialogues, and visual and sound effects throughout the main game and the sub-games. The player was given feedback via display of messages with the first unlocking of a sub-game, the first winning of a sub-game, the unlocking of all sub-games, and the winning of the main game. By unlocking any sub-game, the feedback to the player was the fading of the next sub-game's button (faded to fully seen), and the appearance of the information room's button. By winning any sub-game, the feedback to the player was the change in color of the sub-game's button (grey to colorful), and the appearance of the letter of the game word.
First Sub-Game
The first sub-game of the collection was a very small memory game. There were six rounds in the

game, with each round displaying icons of minerals to the player and then hide them from him/her, asking him/her to remember which ones in a set of eight were shown before. The player would start the game with three lives and with each wrong answer he/she would lose a life. If the player would end up losing all three lives, the game would come to an end and the player was given the choice of starting over or returning to the main game. The icons of the elements increased over the rounds to increase the challenge of the game. If the player reached the end before losing all three lives he/she would win the sub-game.

The player had only one button to press and instructions were given to him/her in the text of that button. Feedback was provided to the player by revealing the correct answers at the end of each round. At the end of the sub-game the player was given the choice to replay the game, go to the first information room, or go to main game. Current number of lives was constantly on the screen with sound effects highlighting a wrong given answer. A button that returned the player to the main game was always available during gameplay.

Second Sub-Game

The second game was like a quiz with graphics. The player was presented with visual and sound effects the environment of a quarry, in which the extraction process of marble had already begun. The player was asked five multiple choice questions about what tool he/she thought should be used next, after the game explained to them what had to happen according to the specific extraction process. Just like the first game, the player was give three lives and with each wrong answer he/she would lose a life, with the game ending if the player would run out of lives. Again, if the player reached the end before losing all three lives he/she would win the game.

Instructions and information were given to the player through a dialogue at the side. Feedback was given to the player by revealing the correct answers at the end of each round. At the end of the sub-game the player was given the choice to replay the game, go to the second information room, or go to main game. Current number of lives was constantly on the screen with sound effects highlighting a wrong given answer. A button that returned the player to the main game was always available during gameplay.

Third Sub-Game

The third game was a simple puzzle game. There was a time limit on this game with the player losing if the time would run out before the puzzle was complete. As would be expected, the game was won only if the puzzle image was completed before the time would run out. Instructions and information were given to the player through a panel with dialogues at the beginning of the game.

Feedback was given to the player by revealing the time the puzzle was completed in at the end of the sub-game. Also, at the end of the sub-game the player was given the choice to replay the game,

view more information about the sketch of the puzzle image, go to the third information room, or go to main game. The timer was constantly on the screen with sound effects highlighting the last remaining seconds. A button that returned the player to the main game was always available during gameplay.
Fourth Sub-Game
The fourth game had to do with the carving of marble. The player had to carve the marble with three different tools to carve three different layers of marble. The player was thus given the choice of one of three tools and had to carve each layer within a given time. If the time would run out before the carving of the specific layer the game would be lost. If the layer was carved in time, the time limit was renewed and the carving of the next layer would begin. With the carving of all three layers in time the player would win the game. Instructions and information were given to the player through a panel with dialogues at the beginning. Feedback was given to the player by revealing the time the carving was completed in at the end of the sub-game. At the end of the sub-game the player was given the choice to replay the game, view more information about the marble artifact, go to the fourth information room, or go to main game. The timer was constantly on the screen with sound effects highlighting the last remaining seconds. A button that returned the player to the main game was always available during gameplay.
Fifth Sub-Game
Just like the third game, this too was a puzzle game with the only purpose of showing to the player the difficulty assembly of a large marble item entails. It should also let the player understand that installation is usually the last stage of marble crafting. The difference with the third game was that the fifth game was a 3D puzzle. The player had to often rotate all the pieces to find exactly the correct place of each piece in all 3 dimensions. Just like the previous two sub-games, it was time limited with the player losing if the puzzle was not completed in time and the player wining if it was. Instructions and information were given to the player through a panel with dialogues at the beginning. Feedback was given to the player by revealing the time the puzzle was completed in at the end of the sub-game. At the end of the sub-game the player was given the choice to replay the game, view more information about the presented exhibit, go to the fifth information room, or go to main game. The timer was constantly on the screen with sound effects highlighting the last remaining seconds. A button that returned the player to the main game was always available during gameplay.

Table 3.2: Game Mechanics for the main game and all sub-games.

3.3.2 Design Process

In a formal design paradigm for serious games [21], it is stated that Gagne's Events of Instruction can be used to describe both a successful game and individual units of gameplay [21]. The formal structure for the serious game design is:

1. Game focus – essence of game description and entry point for gameplay.
2. Didactic focus – subject matter to be taught and entry point for instruction.
3. References to beyond-the-object reference sources which inform the pedagogic content development for the game.
4. Game progression – game units definition.
5. Critical path for gameplay definition and didactic resolution.
6. Pedagogic elements used definition.
7. Description of how formative feedback will be distributed during each unit of gameplay.
8. Description of how summative feedback will be distributed during each unit of gameplay and at the conclusion of gameplay.
9. Description of how replay will be encouraging to assist in retention and remediate shortcomings.

The formal structure of game unit design in serious games is:

1. Scenario exposition - essence of game description and importance in game progression.
2. Didactic exposition – essence of lesson description and importance in curriculum progression.
3. Description of how previous game units and lessons were brought to mind and of how scaffolding was used to reinforce retention and transfer previous lesson to future learning experiences.
4. Scenario crisis development – critical path description and resolution of crisis with gameplay and didactic elements. Evaluation of their fit to one another.
5. Provide direction necessary for the resolution of the game unit and the lesson.
6. Elicit decision/Create actions – Description of how decision making will be elicited during gameplay and how these choices will instruct and advance the game.
7. Provide discernable outcomes to each decision and action that supports both the didactic and designer's focus.

8. Provide a summary of performance at the end of the game unit with proper attribution for shortfalls and successes. Describe how shortfalls could be avoided.
9. Use of scaffolding description in subsequent game units to reinforce the lessons offered in the game unit.

The above mentioned steps were followed to design the game and its sub-games (game units). Following the formal structure for the design of a serious game, the design of the main game was achieved.

Main Game	
Game Focus	The game was focused in the area of marble crafting. The player had to play and unlock 4 out of 5 sub-games (1st is already unlocked), with each sub-stage teaching something new to the player. With each won sub-game the player revealed a letter of the game word and when every letter of the five-letter word was revealed the main game was won. Gameplay started with the player having the role of a marble crafter. In the game environment everything was locked with the exception of the first sub-game in which he/she had to enter.
Didactic focus	By playing the game, the player should learn the following: some of the stages of marble crafting, some of the tools used in marble crafting and in specific stages of it, some of the mineral elements of marble, and some of the marble's extraction techniques. Game started with the player having to play the first sub-game from which he/she could learn about the mineralogical composition of marble.
Pedagogic references	The pedagogic content of the game was provided by the museum of marble crafts of Tinos.
Game progression	The game started with 4 out of 5 sub-games locked, 5 information rooms locked, and the 5 letters of the game word hidden. The player by playing a game regardless of winning or losing would unlock the next sub-game and the corresponding information room. That ensured that the player would go through each game to reach the final sub-game. To reveal a hidden letter the corresponding sub-game had to be won. If all letters of the game word were revealed the game was won. The game units of the game were the five sub-games as information rooms were not actually

	part of the game but just extra contents of information in the case that the player wished to learn more about marble crafting.
Critical path	The game was linear and straight-forward. The path was very clear. The player had to go through each sub-game in turn, from 1 to 5 and win them all to finish the game. The sub-games were in that order so that they could teach the right order of the stages followed in marble crafting.
Pedagogic elements	The teaching methods that were decided to be used for this game were the use of scaffolding and feedback.
Formative feedback	Formative feedback throughout a sub-game was given by displaying the correct answer of a question that the player answered.
Summative feedback	Summative feedback regarding the learning aspects of the game was provided to the player if he/she wished to view it by a button at the end of each game that allowed him/her to enter the corresponding information room and read more about the subject of that particular sub-game. These buttons were available in the main game throughout the game.
Replay's effect	Some of the sub-games were challenging so that replay could be chosen by the player and increase the retention of the learned elements. Also, the sub-games were quite simple and easy to understand by the first play allowing the player to remediate his/her shortcomings from the first play on a second play.

Table 3.3: Gunter's formal structure for the main game.

Following the formal structure for the design of a game unit of a serious game mentioned above, the design of the sub-games was achieved. Regarding the linkage between the lessons, which is the third and the ninth steps described in the formal structure, since every sub-game was of different context, no linkage to previous or following lessons (sub-games) was added between them.

First Sub-Game	
Scenario Exposition	This game was about the mineralogical composition of marble. It was a small memory game, in which the player in each turn needed to remember the icons shown to him/her and after they were hidden from him/her, he/she had to choose them correctly from a bigger set of icons.

	The importance of each sub-game in the game progression was that in order to reveal the corresponding hidden letter of the game word, the sub-game had to be won.
Didactic Exposition	By playing the game, the player should learn some of the mineral elements of marble. It is the first thing to be taught in the curriculum of the main game.
Scenario Crisis	The gameplay of this sub-game was as follows: There were six identical rounds of play, where in the beginning of each round the icons were shown to the player, then they were hidden from him/her, and a larger set of icons (eight icons) was displayed. The player had to choose the set of icons shown to him/her at the beginning of the round. Starting the sub-game the player was given three lives, of which one was lost for every wrong answer. If all three lives were lost the game would come to an end. If the player reached the end of the game with more than zero lives, the game would be won. Each round was more challenging than the previous since the icons shown to the player increased in number, with the final number (sixth round) of icons to remember being six. The icons were presented to the player in the manner of a recipe for the construction of a set of Greek marbles. On the set of icons the names of each mineral was also shown. At the end of each round the marbles created by that specific recipe were shown. The design of the game should promote the learning of the often mentioned minerals.
Resolution	The game was linear and straight-forward. The path was very clear. The player just had to remember the icons in at least 4 out of 6 rounds.
Actions/Decisions	Decisions were elicited through the straight-forwardness of the sub-game. The player had to make a choice to continue playing. These choices affected the game since the outcome of the game (won or lost) affected the main game itself. By winning the sub-game, the corresponding hidden letter of the game word was revealed.
Outcomes	With each action (choice of icons) of the player, the produced marbles from that set of minerals was displayed. With each round the player tried to remember the mineral set, which was the teaching point of this game, while at the same time it provided the player enjoyment and challenge.
Performance	At the end of each round the correct set of minerals was displayed to the

	player regardless of winning or losing that round thus providing valuable feedback in the case of a wrong answer. Also, the chance to see more information about various Greek marbles was available to the player at the end of the sub-game regardless of winning or losing the game.

Table 3.4: Gunter's formal structure for the first sub-game.

Second Sub-Game	
Scenario Exposition	This game was about the extraction process of marble. It was a quiz game, in which the player in each turn needed to understand, by reading the instructions, what the next step of the process was and choose the right tool out of four given choices to perform that action. The importance of each sub-game in the game progression was that in order to reveal the corresponding hidden letter of the game word, the sub-game had to be won.
Didactic Exposition	By playing the game, the player should learn some of the most common marble extraction techniques along with some of the tools used for the extraction of marble. It is the second element of the curriculum's list of the main game.
Scenario Crisis	The gameplay of this sub-game was as follows: There were five rounds of play, where in the beginning of each round a brief description of what was expected to be accomplished was given, and the player was asked to choose 1 out of 4 tools to complete that action. Starting the sub-game the player was given three lives, of which one was lost for every wrong answer. If all three lives were lost the game would come to an end. If the player reached the end of the game with more than zero lives, the game was won. The design of the game should promote the learning of the displayed tools and the described extraction techniques.
Resolution	The game was linear and straight-forward. The path was very clear. The player just had to answer correctly in at least 3 out of 5 rounds.
Actions/Decisions	Decisions were elicited through the straight-forwardness of the sub-game. The player had to make a choice to continue playing. These choices affected the game since the outcome of the game (won or lost) affected the main game itself. By winning the sub-game, the corresponding hidden letter of the game word was revealed.

Outcomes	With each action (choice of tool) of the player, graphics, visual and sound effects would display the use of the correct tool in the required action, promoting the sensation of the action and attempting to retain that new knowledge of the player. That was the teaching point of this game, while at the same time it provided the player enjoyment.
Performance	At the end of each round the correct tool was displayed to the player regardless of winning or losing that round thus providing valuable feedback in the case of a wrong answer. Also, the chance to see more information about more tools was available to the player at the end of the sub-game regardless of winning or losing the game.

Table 3.5: Gunter's formal structure for the second sub-game.

Third Sub-Game	
Scenario Exposition	This game was about the sketching stage of marble crafting. It was a simple puzzle game, in which the player in the given time had to complete the puzzle image. The importance of each sub-game in the game progression was that in order to reveal the corresponding hidden letter of the game word, the sub-game had to be won.
Didactic Exposition	By playing the game, the player should learn the order of the sketching stage in the marble crafting stages sequence, and of course remember the importance of it. It is the third element of the curriculum's list of the main game.
Scenario Crisis	The gameplay of this sub-game was as follows: There was a time limit of 3 minutes, in which the player had to complete the puzzle to win the game. The puzzle image was the image of a sketch. The design of the game should promote the learning of the importance of the sketching stage.
Resolution	The game was linear and straight-forward. The path was very clear. The player just had to complete the puzzle in time.
Actions/Decisions	Decisions were elicited through the straight-forwardness of the sub-game. The player had to make a choice quickly to continue playing. These choices affected the game since the outcome of the game (won or lost) affected the main game itself. By winning the sub-game, the corresponding hidden letter of the game word was revealed.

Outcomes	With each action of the player, the puzzle came closer to its completion and the image of the sketch was being revealed. That was the teaching point of this game, while at the same time it provided the player enjoyment.
Performance	At the end of the sub-game if the player had won, the time in which he/she had completed the puzzle was presented to him/her. Also, the chance to see more information about the puzzle image was available to the player at the end of the sub-game regardless of winning or losing the game.

Table 3.6: Gunter's formal structure for the third sub-game.

Fourth Sub-Game	
Scenario Exposition	This game was about the carving stage of marble crafting. It was a very simple game, in which the player in the given time had to carve the marble with the right tool. The importance of each sub-game in the game progression was that in order to reveal the corresponding hidden letter of the game word, the sub-game had to be won.
Didactic Exposition	By playing the game, the player should learn the marble carving technique, the tools used in it, and the order of the carving stage in the marble crafting stages sequence. It is the fourth element of the curriculum's list of the main game.
Scenario Crisis	The gameplay of this sub-game was as follows: There was a time limit of 90 seconds, in which the player had to choose one of three tools to carve a layer of the unprocessed marble. By choosing the correct tool and tabbing on the marble pieces of the first layer, the pieces would get removed. The player had to remove all pieces of that layer in the time given to proceed in the sub-game. When the first layer was completely removed, the time was renewed and the same thing had to happen for the second layer using a second tool out of the three. Same goes for the third and final layer. The game was won if all three layers were removed completely in the given time. The image and name of each tool was shown to the player throughout the sub-game to increase the chance of retaining that tool in the player's memory. The design of the game should promote the learning of the three used tools and the carving technique.

Resolution	The game was linear and straight-forward. The path was very clear. The player had to remove all pieces of each layer in the given time using the correct tool for each layer.
Actions/Decisions	Decisions were elicited through the straight-forwardness of the sub-game. The player had to make a choice quickly to continue playing. The player had to choose in the beginning of the sub-game which tool to use. When choosing the wrong tool and nothing happened, the player had to understand that he/she must try another tool. These choices affected the game since the outcome of the game (won or lost) affected the main game itself. By winning the sub-game, the corresponding hidden letter of the game word was revealed.
Outcomes	With each action of the player, the marble came closer to its final carved status and was being revealed. That was the teaching point of this game, while at the same time it provided the player enjoyment.
Performance	At the end of the sub-game if the player had won, the time in which he had carved the marble was presented to him/her. Also, the chance to see more information about the carved marble piece was available to the player at the end of the sub-game regardless of winning or losing the game.

Table 3.7: Gunter's formal structure for the fourth sub-game.

Fifth Sub-Game	
Scenario Exposition	This game was about the assembly-installation stage of marble crafting. It was a simple 3D puzzle game, in which the player in the given time had to complete the puzzle. The importance of each sub-game in the game progression was that in order to reveal the corresponding hidden letter of the game word, the sub-game had to be won.
Didactic Exposition	By playing the game, the player should learn the order of the assembly-installation stage in the marble crafting stages sequence, and of course remember the importance of it. It is the fifth element of the curriculum's list of the main game.
Scenario Crisis	The gameplay of this sub-game was as follows: There was a time limit of 4 minutes, in which the player had to complete the puzzle to win the game. The puzzle was a representation of an exhibit of the museum. The

	design of the game should promote the learning of the importance of the installation stage.
Resolution	The game was linear and straight-forward. The path was very clear. The player just had to complete the puzzle in time.
Actions/Decisions	Decisions were elicited through the straight-forwardness of the sub-game. The player had to make a choice quickly to continue playing. These choices affected the game since the outcome of the game (won or lost) affected the main game itself. By winning the sub-game, the corresponding hidden letter of the game word was revealed.
Outcomes	With each action of the player, the puzzle came closer to its completion and the exhibit took form. That was the teaching point of this game, while at the same time it provided the player enjoyment.
Performance	At the end of the sub-game if the player had won, the time in which he had completed the puzzle was presented to him/her. Also, the chance to see more information about that specific exhibit was available to the player at the end of the sub-game regardless of winning or losing the game.

Table 3.8: Gunter's formal structure for the fifth sub-game.

3.4 Design Issues

This section discusses possible features of the game that were either approved or dismissed due to inability for a variety of reasons explained for each case. Certain aspects for which attention should be paid during the design and implementation of the game are also discussed.

Tangible devices are always fun and attractive, especially in the museum area along with an enjoyable game. Unfortunately there are traps when deciding to use that kind of attraction in a game. A research of the Electronic Guidebook project [25] showed that visitors found it difficult and cumbersome to carry handheld devices while operating the museum exhibits [24]. In the case of the mystery in the museum experiment [06], one finding was that the PDAs drew most of the attention of the players, preventing them to pay much attention to the museum surroundings. For that reason, and due to increased expenses, it was decided that the game would be contained in a computer screen.

Having that in mind, the most fascinating choice would be to use a table-top. People are always gathering around table-tops as they are a representation of innovative technology that is not easily available. The problem, besides the cost, is that there is also always the danger that visitors might just be interested in the technology of the table-top rather than the content of it [34]. Thus, a simple pc or tablet would be suitable for our small game.

Having defined the position of the game in the museum, it should be taken into account the significant role that the appearance of the game and its surroundings have. A walk-up-and-use table should be self-explanatory and clearly indicate its purpose [22]. No instructions should be needed when attempting to engage such a tabletop [28]. So, in the design of the game, it should be noted that the location of the game itself, and the way of its presentation has a bearing in the popularity of the game.

Moving to the game itself, Marshall et al. [34] highlights the importance of the first touch, suggesting that users might not give a second chance to the interface if they do not experience a successful initial interaction [40]. Another note is that interactive displays should not be designed in a way that is too complex for users to understand [40]. Findings of a psychophysiological evaluation [07] showed amongst others, that some players felt frustrated by their inability to win the game, with a note that this difficulty could impede learning. In conclusion, the game should be as simple as possible but at the same time compelling enough.

Now proceeding to the museum visit experience, pre-visit preparation improves the chance of learning and includes the students' cognitive, psychological and spatial orientation to the museum [52]. Mystery in the museum's [06] plot involved a number of puzzles that related to the exhibits with the solution bringing rewards to the players. Pre-visit session of the teacher with the students was needed in order to deepen their background in the subject. Of equal importance are post-visit activities [52].

Pre-visit sessions are of course important and valuable. In the case of this thesis though, due to some limitations it was not possible for such an arrangement to be achieved. For example, the evaluation period was in August which is a time when schools are closed for vacations so it was very difficult to invite an organized class to the museum. For that same reason, peer to peer teaching was also not included in the aspects of the designed game.

Another feature that was considered a possibility was the inclusion of audible messages in the game. However, there was the likelihood that the children would not be able to listen to the dialogues in the museum environment. Of course, headsets could solve this problem, yet there were cases where technology isolated the visitors, when in order to hear audio they wore headsets which tended to separate them from their surroundings [31]. On the account of these remarks, no audible messages were included in the game.

Museum visits can expose students to subject-matter that cannot be effectively covered in the classroom [52]. As Yatani et al. [56] note, children often pay no attention to exhibits that only present information and do not allow any response from the child. By playing with the object on-screen, the visitor comes close to playing with it in real life, which is the way all of us, at base, like to learn [13]. Regarding these aspects, the manipulation of existing artifacts in the museum exhibits through the interactivity of the game could prove useful in gaining the attention of the children towards the whole exhibit.

An important mark worth noted is that that reword can be applied at the completion of participation and that it sets the stage for further engagement [21]. According to that remark, multiple rewards were provided during the game, since even after losing a sub-game the player would receive the reward of having unlocked the next sub-game and the corresponding information room of that sub-game.

The game was designed to be used in a museum for a limited time by each visitor, thus it was not designed with the purpose of being played many times by the same player. The player can keep replaying the sub-games to win the game and expose the game word, but it is believed that by playing the main game once, if enough interest exists, the player can learn everything this game has to offer.

Chapter 4
The Game

Following the design stage, the implementation of the game should be accomplished. In this Chapter, the concept of the game is provided, the chosen technology is given, a description of the main game, its sub-games, and its information rooms is presented, and finally some implementation issues are reviewed.

4.1 Concept

The concept of the game is quite simple with a very clear game story. Basically the story gives the player the role of a marble crafter and it guides him through various stages of marble crafting. The game contains five sub-games with almost each game playing the role of a stage of the marble crafting process. The main game and the five sub-games are described in detail in following sub-sections.

4.1.1 Game Goal

The game consists of various sub-goals but the final goal to win the game is to complete the word of the game by winning all the sub-games that the main game contains.

4.2 Chosen Technology

As noted in the compatibility requirements of the designed game, the implemented game should be available for various consoles. For that reason, a way to design a game that could be exported to various consoles had to be found.

The chosen technology for implementing the game was Unity[1]. Through the Unity game engine v5.1.0f3, a designed game whether 2D or 3D or a combination of the two, could be easily exported to any well-known gaming console. The implemented game was a combination of 2D and 3D worlds, with most of the game being in a 2D world with sub-games 2, 4, and 5 being in a 3D world.

The chosen scripting language for the designed game was Javascript, and the gaming console for the game was android. The decision was based on the ease of installation of the game on an android tablet that could just as easily be placed in any area of the museum.

4.3 Main Game

The game is mostly designed based on Gagne's guidelines. According to Gagne [17], and as stated before, the nine events that are required for learning to occur are:

1. Gain the learners attention
2. Inform the learners of the objectives
3. Stimulate recall of prior learning
4. Present stimulus or lesson
5. Provide learning guidance and instruction
6. Elicit performance
7. Provide feedback
8. Assess performance
9. Enhance retention and transfer

In order to link the implementation of the game with the design of it, how and where these nine events apply is stated for the main game and all the sub-games of it in this Chapter.

[1] https://unity3d.com/

Figure 4.1: The screen of the main game after being won.

4.3.1 Description

The main game is called MarbleGames and is basically a map of the island of Tinos. On that map, there are the five sub-game buttons. By pressing one of those buttons the player is transferred to that specific sub-game.

The game starts by giving the player the choice to decide in what language the game will be played in. There are only two options, Greek and English. Choosing the English language, the game begins by showing two messages in sequence to provide the story of the game. Clicking the "Play" button lets the player see the main game screen. In the island of Tinos, there are five sub-game buttons. The only one available is the button that leads to the first sub-game. The player has also the choice of pressing the "Exit" button. That allows the player to exit the game, return to it, or restart the game.

After playing the first sub-game and losing, the second sub-game and the first information room get unlocked. A message appears to inform the player about that fact and congratulate him/her. The screen then includes a path that appears between the two stages and both buttons of sub-games one and two become available. Another button has also now appeared at the top right of the screen, which is the button that leads to the first information room. A message of

encouragement to attempt once again to play the first game to win it is written on the sign of the main game.

The first time a sub-game is won, an information and congratulations message is again displayed to the player to encourage him/her to keep playing and win the game. Now, if the second sub-game is won, the button of the won sub-game becomes colorful, another path appeares for the third sub-game that is also now available for play, the second information room gets unlocked, and the second letter of the game word is revealed in the upper left corner of the game screen. By playing the game and reaching the end, unlocking all five sub-games and all five information rooms, a congratulations message is again displayed to the player.

Win all five sub-games and the final congratulations message appears to let the player know that he/she won the game. This message gives the choice to the player of keep playing the already won sub-games or start the game over. By winning the game the final game screen becomes as showed in figure 4.1, and the game word is finally revealed. The game word is "ΤΗΝΟΣ", Greek for Tinos.

Gagne's Events Applications For the Main Game	
1.Gain the learners attention	Elements that are expected to gain the learners attention are: The graphics, sound effects and animations of the game.
2.Inform the learners of the objectives	Learners are informed of the objectives of the game from the beginning with messages displayed to them.
3.Stimulate recall of prior learning	Through the main game the choice of viewing information about various sections associated with the museum is available to the player during gameplay through buttons that lead to information rooms.
4.Present stimulus or lesson	The player should learn the sequence of the usual stages of marble crafting.
5.Provide learning guidance and instruction	In order to learn that sequence, the rules of the game constrain the progression of the player in a linear sequence. The player has to play the stages in the right order to reach the finish and complete the game. That should allow the player to keep in mind that order.
6.Elicit performance	The sub-games of the main game are unlocked just by playing the previous sub-game of that specific one. A game that is just unlocked but was not won at least once has a greyed icon. A game that was won at least

	once has a colorful icon. That informs the player of his/her progression and at the same time provides a motivation to replay sub-games that was not won on the first try.
7.Provide feedback	Feedback is provided with the use of messages, graphics and sound effects. Messages on the sign, colorful icons of sub-games and more.
8.Assess performance	Performance is assessed mostly through the game word. To win the game the player must complete the game word. The five letters of the game word show how much closer to winning the game the player is. The revealed letters are always appearing on the screen of the main game.
9.Enhance retention and transfer	The choice of viewing information about various sections associated with the museum through information rooms is allowing retention and transfer. That of course depends on the players' interests.

Table 4.1: Gagne's events linkage to the main game.

4.4 Sub-Games

Starting with the first sub-game, all sub-games of the collection are described here, and linkage to Gagne's events is provided for each one of them. The first sub-game is called MarbleCreations because it deals with the creation of marble.

4.4.1 MarbleCreations

Figure 4.2: MarbleCreations during gameplay.

The game starts with two messages in sequence that let the player know what he/she has to do in this first game. As the game begins, the player must memorize the two icons shown in the first recipe and then press the button “Choose Ingredients”. The button “Exit” is always available to return the player to the main game during gameplay. The remaining lives are also shown at all times. Pressing the arrow button hides the ingredient icons on the left and displays a set of eight icons on the right. The message on the left lets the player know that he/she has to choose the correct ingredients, if he/she can remember them.

After choosing some icons, and pressing the “Done” button, the correct icons become green and the wrong icons red. In the case that the player was wrong, the message on the right informs him/her that he/she gave a wrong answer and that he/she has lost one life. That is also apparent by the remaining lives shown thoughout the game. Now the screen of the game becomes as shown in figure 4.2.

At the left side, the marbles that are created by the icons that appear green on the right, are shown as buttons. By pressing a marble button, a new panel appears that displays a few information about that specific type of marble. When the player loses all three lives, the game ends with a screen that allows him to replay the game, go to the first information room or go back to the main game. Winning the game a congratulations message appears and the player is presented with the same three choices. To win the game, the player must reach and answer the sixth and final round with remaining lives > 0.

The minerals on the right, always appear with their name so that the player can still remember them after the game is over. The number of icons that the player has to remember through rounds one to six are: 2, 3, 4, 4, 4, and 6. That sequence was chosen in order to increase the challenge as the game moves to its end.

Gagne's Events Applications for the First Sub-Game	
1.Gain the learners attention	Elements that are expected to gain the learners attention are: The graphics, sound effects and animations of the game. The nature of the game, which as a small memory game is believed to be intriguing.
2.Inform the learners of the objectives	Learners are informed of the objectives of the game from the beginning with messages displayed to them.
3.Stimulate recall of prior learning	No recall was desired since this was the first sub-game of the collection either way.
4.Present stimulus or lesson	Players should learn at least some of the minerals of which marble is usually consisted of.
5.Provide learning guidance and instruction	Instructions were given mostly by messages displayed to the player. Guidance was also provided by the simplicity of the game. Constant dialogues and just one button to be pressed. The names of the icons were displayed in every round of the game to help the players retain them in their memory. Also, the marbles created by each recipe were shown at the end of each round, and information about them could be viewed with the push of a button.
6.Elicit performance	The game started with just two icons to be remembered and ended with six on the last round. This was chosen in order to let the player get used of the game at first, and to increase the difficulty during rounds so that performance could be elicited. If the game is lost, an encouraging message to the player to try again is displayed. The limited number of lives was also an assisting element.
7.Provide feedback	Feedback is provided with the use of messages, graphics and sound effects. For example, the correct and incorrect icons of each round are displayed to the player. A message also informs the player if he/she chose the correct ingredients and if not, that they have just lost a life.
8.Assess	During gameplay the remaining lives of the player can be seen constantly,

performance	to let him/her know of the current status of the game.
9.Enhance retention and transfer	At the end of the game, the player is presented with the choice of viewing some more information about various Greek marbles. That choice is always available throughout the main game to help retention of gained knowledge.

Table 4.2: Gagne's events linkage to MarbleCreations.

4.4.2 MarbleExtractions

Figure 4.3: MarbleExtractions during gameplay.

The second game of the collection is called MarbleExtractions. The game starts in 3D world quarry, with a surface of marble exposed from the mountain, showing clearly that the extractions process is at hand. The player receives the message that help is needed from him/her in order to extract the marble from the mountain. A second message informs the player that questions need to be answered correctly in order for the marble to be successfully extracted.

By pressing the "Play" button the first description is shown. Each round of the second sub-game asks the same question "Which tool will you use?". What differs, is the description given on the right side of the screen. The dialogue explains to the player what needs to be achieved, and the player has to answer the question by choosing the tool that he/she thinks is correct for that task. Again, the "Exit" button is available at all time during gameplay to return the player to the main game. The remaining lives are also shown to the player at all times.

After choosing a tool out of the four presented to him/her, the correct answer is shown by getting a green color, while the wrong answers get the red color. Sound effects also indicate to the player if he/she answered correctly, while in the case of a mistake, a life is removed from the remaining lives panel of the screen. Right after the choice of the player, all dialogues and buttons are blown away for a few seconds, and graphic effects and animations present to the player the action that was described so that he/she can understand what exactly had to be achieved and what tool was used for the described task.

Moving to the next round, the dialogues and buttons return, with a different description and the same question with four different tools as possible answers. On the top right dialogue, a congratulations message appears if the player answered the previous question correctly, and an encouraging message appears to the player if he/she answered incorrectly.

If the player loses all three lives before reaching the fifth and final question, the game is over. If the player reaches and answers the final question with remaining lives > 0 then he/she wins the game. After answering the fifth question and wins, a button with a bomb is presented to the player and a message informs him that only the final step of the extraction is left. Pres that button and again animations display to the player the small explosion that completes the extraction of the marble. After that a congratulations and thankful message is presented to the player. If the player loses, an encouraging message is shown, urging the player to try again if he/she wishes.

Regardless of winning or losing, the choices for the player at the end of the game are the same. The player can replay the game, go to the second information room, or go back to the main game. The five questions of the game are of equal difficulty since the player usually doesn't know the extraction techniques used. During gameplay, on the right panel, it is described which extraction technique is used. In total, two different extraction techniques are presented to the player and ten different tools and pieces of equipment are shown in use.

Gagne's Events Applications for the Second Sub-Game	
1.Gain the learners attention	Elements that are expected to gain the learners attention are: The graphics, sound effects and animations of the game. This 3D game contains many animations that show the use of each tool of the excavation process.
2.Inform the learners of the	Learners are informed of the objectives of the game from the beginning with messages displayed to them.

objectives	
3.Stimulate recall of prior learning	No recall was desired.
4.Present stimulus or lesson	Players should learn at least some of the tools used during the excavation stage of marble, and the two techniques presented in this game. They also should learn the usual position of this stage in the whole of the marble crafting stages.
5.Provide learning guidance and instruction	Instructions were given mostly by messages displayed to the player. Guidance was also provided by the simplicity of the game. An information panel explained the techniques to the player. The animations showed to the player how each tool should be used. The names of the tools were constantly shown to help retaining them in the player's memory.
6.Elicit performance	The animations of the game and the fact that the player had a limited number of lives were elements used in order to elicit performance.
7.Provide feedback	Feedback is provided with the use of messages, graphics and sound effects. For example, the correct and incorrect icons of each round are displayed to the player. A message also informs the player if he/she chose the correct ingredients and if not, that they have just lost a life.
8.Assess performance	During gameplay the remaining lives of the player can be seen constantly, to let him/her know of the current status of the game.
9.Enhance retention and transfer	At the end of the game, the player is presented with the choice of viewing some more information about various tools. That choice is always available throughout the main game to help retention of gained knowledge.

Table 4.3: Gagne's events linkage to MarbleExtractions.

4.4.3 SketchPuzzle

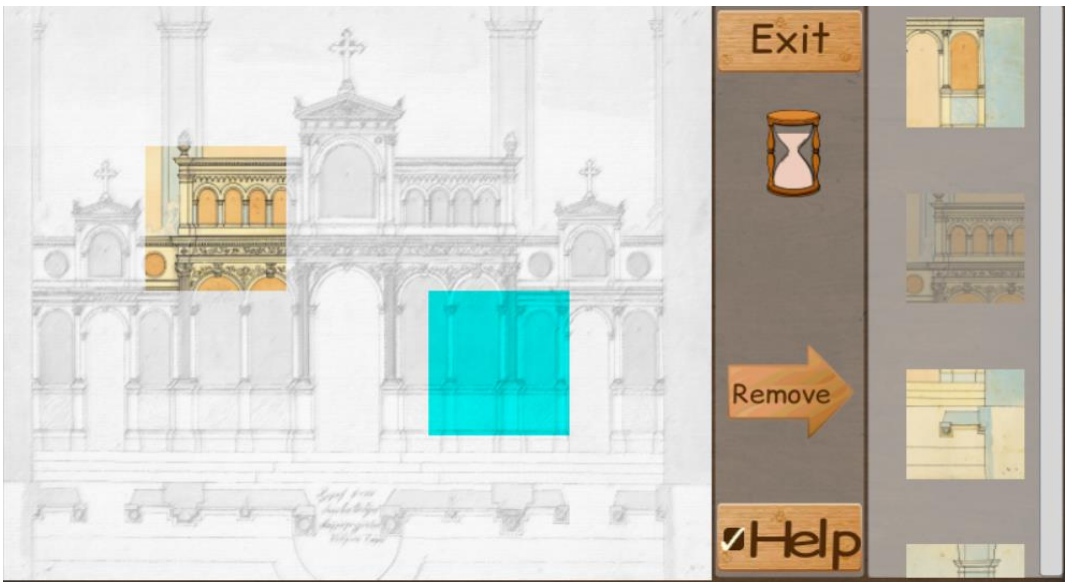


Figure 4.4: SketchPuzzle during gameplay.

Third sub-game is the SketchPuzzle. It is obviously a puzzle with the puzzle image being a known sketch of a Temple. The game starts by informing the player that he/she has to complete the puzzle in time. By pressing the "Play" button a panel of instructions appears to explain how the controls are used and what every element and button in the screen is used for. Pressing the button "Got it" blows that panel away thus starting the game. "Exit" button, "Help" button, and the timer are always available during gameplay.

The given time to complete the puzzle is three minutes. The "Exit" button as before takes the player to the main game, whereas the "Help" button toggles the background image of the puzzle from a book image to a more helpful one, which is the puzzle image softened. The way the game is played is this: the player presses on a square on the left side of the screen, the square takes a light blue color to highlight that it is selected, then the player through the scrollable panel on the right presses the piece he/she wants to be placed on the selected position. Having it placed at a position, if the player made a mistake, he/she can again highlight that piece on the left panel, and by pressing the "Remove" button, the piece will return to its original place on the right panel.

If every piece is placed in its correct place in the given time, the game is won and a congratulations message is appeared to the player. If the time expires before the completion of the puzzle, the game is over and an encouraging message to try again is shown to the player. This game is mostly entertaining, with the only teaching aspect of it being that the player should remember that the sketching stage is the third in line as it showed through the main game.

The nature of the game and the time limit placed upon it, should make the game challenging enough to make the player wanting to replay it. It is quite difficult to complete the puzzle in the given time without the provided help, but that was added as an extra challenge to puzzle lovers. The given time was sufficient to make the player at his/her first play barely complete the puzzle or fail while being very close to finishing it, in order to engage the player to play at least one more time. Regardless of winning or losing, the player is given the same four choices: A choice to replay the game, a choice to go to the third information room, a choice to go to the main game, and a choice to view some information about the sketch of the puzzle image.

Gagne's Events Applications for the Third Sub-Game	
1.Gain the learners attention	Elements that are expected to gain the learners attention are: The graphics, sound effects and animations of the game. The nature of the game, which as a simple puzzle game is believed to be engaging.
2.Inform the learners of the objectives	Learners are informed of the objectives of the game from the beginning with messages displayed to them.
3.Stimulate recall of prior learning	No recall was desired.
4.Present stimulus or lesson	Players should learn at least the position of the sketching stage in the stages of marble crafting sequence.
5.Provide learning guidance and instruction	Instructions were given mostly by messages displayed to the player. Guidance was also provided by the use of a starting instructions panel which explained how the controls and elements of the game should be used, with the use of controls and images. The puzzle image was an image of a sketch to help the player keep in mind what this stage was about.
6.Elicit performance	The nature of the game is believed that it should keep the player immersed and focused in the game. If the game is lost, at the end of the game, an encouraging message to the player to try again is displayed. The limited time was also an assisting element. Help was provided to make the game easier in the case that the player felt that the game was too difficult to win.
7.Provide feedback	Feedback is provided with the use of messages, graphics and sound effects. For example, if a square was chosen it was highlighted with a light blue color. An always displaying timer informs the player of the

	remaining time. If the remaining time is close to expiring, an alarming sound informs the player about that fact.
8.Assess performance	During gameplay the remaining time of the game can be seen constantly. At the end of the game, if the puzzle was completed, the time in which the game was won is shown to the player.
9.Enhance retention and transfer	At the end of the game, the player is presented with the choice of viewing some more information about the specific sketch of the puzzle image. The player also has the choice of viewing more sketches and information about them through the third information room. That choice is always available throughout the main game to help retention of gained knowledge.

Table 4.4: Gagne's events linkage to SketchPuzzle.

4.4.4 MarbleCarvings

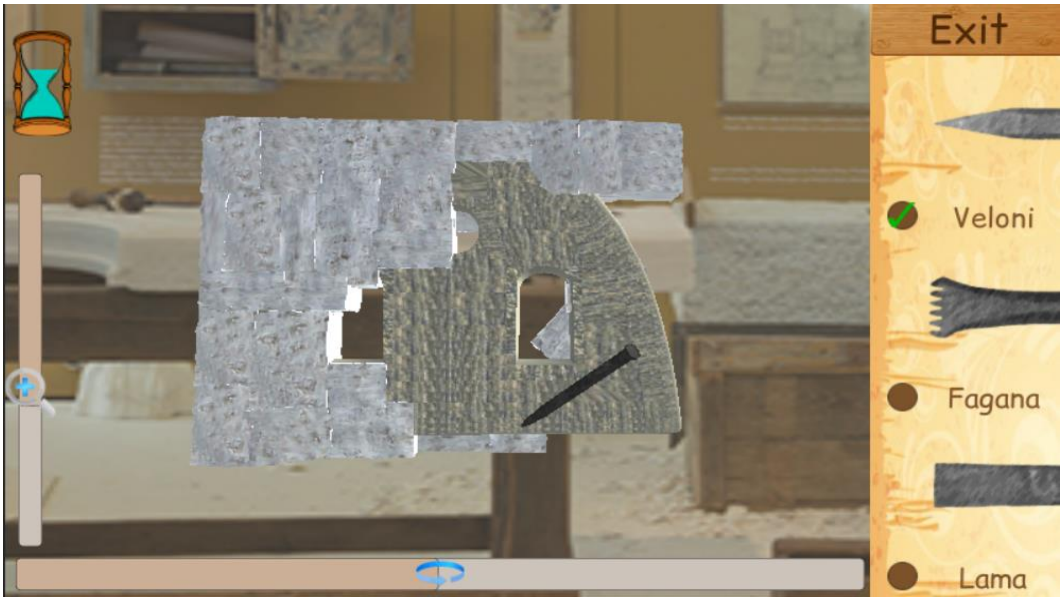


Figure 4.5: MarbleCarvings during gameplay.

The fourth sub-game of the collection is called MarbleCarvings, and is as expected relevant to the carving stage of marble crafting. This game starts by stating to the player that to make the deadline he/she must carve the marble in time, and informs him/her that the right tool must be chosen to carve each layer in time. Just like the previous sub-game, by pressing the "Play" button, an instructions panel is displayed to explain the controls and the elements that appear on the screen of the game.

These elements and controls are: The timer, a side panel from which the player chooses the tool to be used, a bottom bar that is used for rotating the marble piece which needs to be carved, and another bar at the left side of the screen that is used to zoom in and out. Just like every other sub-game, the "Exit" button is always available to take the player to the main game screen.

As shown in figure 4.5, there are three tools from which the player can choose to use. If the player choses the correct one and presses on any one pieace of the corresponding layer, that piece will get destroyed. If the player chooses another tool other than the correct one, nothing will happen. The three tools are actually placed in the right order to be used starting from the top and ending at the bottom. Each layer has to be carved fully for the time to be renewed.

A time limit of 90 seconds is given to the player in order to carve each layer of the game. There are in total three layers on which a different tool has to be used. When the first layer is completely carved, the time is renewed and the player needs to choose another tool and start carving the second layer. If he/she succeds, the time is renewed for the last time, and the third and final layer has to be carved. In some cases, the marble piece must be rotated to be carved from both sides.

If the player carves fully the last layer in time, the game is won and a congratulations message appears. If the player does not carve any one of the three layers in time, the game is over and an enouraging message appears to the player, in order to motivate him/her to try again. At the end of the game, the player has the choices of replaying the game, going to the fourth information room, going back to the main game, or viewing some information about the carved marble piece.

The three tools are always appearing on the screen, with their names under them, to help the player retaining them in his/her memory. Also, sound and visual effects and animations help immerge the player in the game. The time limit was chosen to be 90 seconds to make the game challenging and keep the player focused during gameplay.

Gagne's Events Applications for the Fourth Sub-Game	
1.Gain the learners attention	Elements that are expected to gain the learners attention are: The graphics, sound effects and animations of the game.
2.Inform the learners of the objectives	Learners are informed of the objectives of the game from the beginning with messages displayed to them.
3.Stimulate recall of	No recall was desired.

prior learning	
4.Present stimulus or lesson	Players should learn at least the names and the uses of the three tools displayed in the game. They also should learn the carving technique and the usual position of this stage in the marble crafting stages.
5.Provide learning guidance and instruction	Instructions were given mostly by messages displayed to the player. Guidance was also provided by the use of a starting instructions panel which explained how the controls and elements of the game should be used, with the use of controls and images. The names of the three tools were shown throughout gameplay to help the player keep them in his/her mind.
6.Elicit performance	The nature of the game is believed that it should keep the player immersed and focused in the game. If the game is lost, at the end of the game, an encouraging message to the player to try again is displayed. The limited time was also an assisting element. The 3D mode of this game should provide some extra interest.
7.Provide feedback	Feedback is provided with the use of messages, graphics and sound effects. For example, if the wrong tool was chosen nothing would happen if the player pressed on any piece of a layer. An always displaying timer informs the player of the remaining time. If the remaining time is close to expiring, an alarming sound informs the player about that fact.
8.Assess performance	During gameplay the remaining time of the game can be seen constantly. At the end of the game, if the puzzle was completed, the time in which the game was won is shown to the player.
9.Enhance retention and transfer	At the end of the game, the player is presented with the choice of viewing some more information about the specific exhibit of the game. The player also has the choice of viewing more exhibits and information about them through the fourth information room. That choice is always available throughout the main game to help retention of gained knowledge.

Table 4.5: Gagne's events linkage to MarbleCarvings.

4.4.5 GameOfMarbleThrone

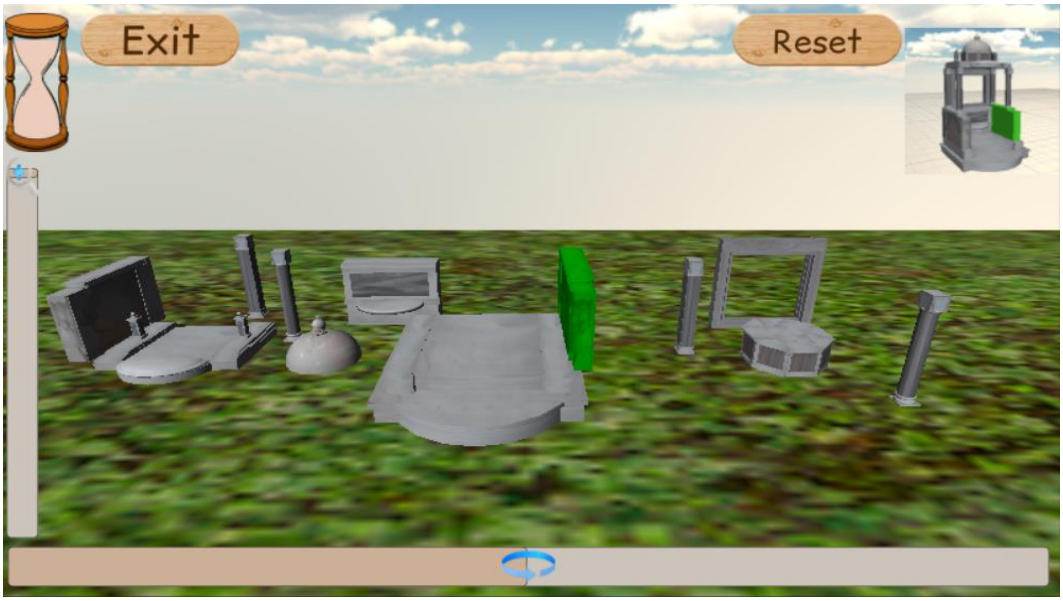


Figure 4.6: GameOfMarbleThrone during gameplay.

The final sub-game of the collection is called GameOfMarbleThrone. It is another puzzle game, but in a 3D form. The game starts with instructions to the player, that he/she must assemble the throne in time, and it highlights the importance of the rotation bar for this game. Clicking the "Play" button, the timer starts and the player need to assemble the throne, which is an existing exhibit of the museum.

Two buttons are always available to the player during gameplay. "Exit" button takes the player to the main game, while "Reset" button moves every piece of the throne that is not fitted on its correct place at its initial position. That button is available in case things get complicated and pieces are put in front of others or outside of the screen boundaries. By touching a piece, the correct place of it is shown to the player on a small image on the top right of the screen to make the game easier for play.

To provide feedback to the player, if the piece that is being dragged is somewhere close to its correct position, that piece takes a green color. If released at that point, the piece gets in its correct position. If the piece that is being dragged is placed in a forbidden position, like under the ground, it take a red color to show that is not an appropriate position for it. If released at that point, the piece goes back to its initial position. If placed in its correct position, a sound effect infroms the player about that fact.

Rotation needs to be constant in order for the player to understand at which point of the three axes the piece needs to be placed. Just like the previous sub-game, a rotation bar and zoom bar are available to the player. Also, the timer is always appearing on the screen. The time given is 4 minutes. If the player completed the puzzle in time the game is won and again a congratulations message appears. If the puzzle is not completed in time, the game is over and an encouraging message appears for the player to try again.

At the end of the game, the player has the choices of replaying the game, going to the fourth information room, going back to the main game, or viewing some information about the throne exhibit. This stage learning objective is to teach the player the importance and difficulty of the assembly-installation stage. It also shows the stage's place in the marble crafting process, which usually is the last stage.

Gagne's Events Applications for the Fifth Sub-Game	
1.Gain the learners attention	Elements that are expected to gain the learners attention are: The graphics, sound effects and animations of the game. The nature of the game, which as a 3D puzzle game is believed to be engaging.
2.Inform the learners of the objectives	Learners are informed of the objectives of the game from the beginning with messages displayed to them.
3.Stimulate recall of prior learning	No recall was desired.
4.Present stimulus or lesson	Players should learn at least the position of the assembly-installation stage in the stages sequence of marble crafting.
5.Provide learning guidance and instruction	Instructions were given mostly by messages displayed to the player. The puzzle artifact was an existing exhibit of the museum to help the player keep it in mind.
6.Elicit performance	The nature of the game is believed that it should keep the player immersed and focused in the game. If the game is lost, at the end of the game, an encouraging message to the player to try again is displayed. The limited time was also an assisting element.
7.Provide feedback	Feedback is provided with the use graphics and sound effects. For example, if a dragged piece was placed in a correct or a forbidden position it got a green or a red color respectively. An always displaying

	timer informs the player of the remaining time. If the remaining time is close to expiring, an alarming sound informs the player about that fact. When a piece is dragged, its correct position on the throne is displayed on a small image on the screen.
8.Assess performance	During gameplay the remaining time of the game can be seen constantly. At the end of the game, if the puzzle was completed, the time in which the game was won is shown to the player.
9.Enhance retention and transfer	At the end of the game, the player is presented with the choice of viewing some more information about the specific exhibit of the museum. The player also has the choice of viewing more key sides and information about them through the fifth information room. That choice is always available throughout the main game to help retention of gained knowledge.

Table 4.6: Gagne's events linkage to GameOfMarbleThrone.

4.5 Information Rooms

Figure 4.7: Marble information room

The information rooms are available to the player at any time during gameplay, after they are unlocked. These information rooms can be considered as extra information just in case the player is interested in learning more. For that reason, they are not actually considered as parts of the learning game and thus it is not expected (neither evaluated), from the player to gain new knowledge from them. There are five in total information rooms located in the game. All these information rooms have basically the same appearance and controls but contain different data.

Through these rooms the player can see pictures and read more details about the following:

- Various Greek marbles
- Marble crafting tools
- Marble crafting sketches
- Exhibits of the Museum of marble crafts of Tinos
- Various points of interest related to marble crafting

The information room has two panels. In the left scrollable panel, various sorted buttons are available to be pressed. Pressing one of them displays information about a specific element on the right panel. For example, in the case of Greek marbles, the name of the marble, the origin of it, its color, its mineralogical composition, along with a map that displays its origin, are appearing on the right panel of the information room. As a background image of each information room, a photograph of that particular section of the museum is usually placed. A "Menu" button is appearing on the leftmost part of the screen to take the player back to the main game**.**

4.6 Implementation Issues

During the implementation of the whole game, some regards were taken into account. Some of the most important ones are described in this section. For example, interactions and progression mechanics in the game were implemented in a way, as to be closely related to the game's educational activities and goals [26]. The user interface was implemented in the concept of being as transparent as possible, so that the player could focus on playing and not on how to play [54].

LGs should not have long phases, unrelated to educational activities. However, this does not forbid having short moments of pure entertainment in order to relax learners and increase their self-confidence before starting harder exercises [26]. Based on that comment, some of the sub-games (SketchPuzzle, GameOfMarbleThrone), were implemented to be more fun and entertaining with less educational progress, to let the player relax from the whole experience.

On the other hand, since challenge is a crucial element to captivate learners' attention with the level of appropriate difficulty of a LG being neither too low, neither too high [26], the final sub-game was implemented with a hint of complexity, to add that extra challenge for the player to finish the game.

The recognition of success expressed by scoring, trophies, congratulation messages, unblocking elements of the game, gives the player the sensation that they did well and pushes them to continue [26]. Also, according to Damasio [08] and a study of the National Research Council [38], the emotional responses, triggered when players win, have a positive effect on their level of attention, their memory and also their capacity to make decisions [26]. Due to that fact, during the whole game, congratulation messages and various types of awards were plentiful to help increase the players gaming experience and learning.

An important note that through the entire designing and implementation of the game was taken into account was the following: A balanced game is one where the main determining factor for success of the player is the skill level of the player [42].

Chapter 5
Empirical Evaluation

In this chapter the evaluation questions are set, the evaluation methodology is described in detail, the reliability analysis is provided, and the evaluation experiment is presented.

5.1 Evaluation Questions

From the evaluation process it will be attempted to collect data that can provide answers to the following questions. It should be noted that questions Q1 and Q4 emerged directly from the research questions of this thesis whereas questions Q2 and Q3 were added in the evaluation questions set after examining the notes of the evaluation manager listed in sub-section 5.4.3.1.

Q 1. Does the game increases the knowledge of the players about marble crafting?
Q 2. Do female players achieve more learning than male players?
Q 3. Do older players achieve more learning than younger players?
Q 4. Is there a relationship between the initial motivation of the player and his/hers final satisfaction?

5.2 Evaluation Methodology

MarbleGames is a game designed in the concept of being placed in a museum of marble crafts. The goal of this game is to help its players, and particularly the youngest of them, to learn some basic things related to marble crafts in a more fun way than the conventional one. To reveal if the goal of the game could be fulfilled, the game itself had to go through an evaluation process. This section describes in detail the methodology used for that specific process.

The analysis methods are the tools and techniques available to the Analyst (e.g., interview, observation, questionnaires). The learner questionnaire is a particular analysis instrument to profile the learner [10]. A common approach to profile learners is through self-assessment, e.g. a form that the participant completes. The most common approach to analyze the effectiveness of SGs is a comparison of pre- and post-test results to measure learning effects [37]. An evaluation methodology that takes the above mentioned factors into account is the SEGEAL evaluation methodology [43].

The goal of the SEGEAL evaluation methodology was to evaluate a SG that was intended to be placed in various schools. The SEGEAL methodology [43] was consisted of three stages. In the first stage, called Alpha testing, in an emulation of an operational testing, the members of the development team that were not involved in that particular part of the game played the game and made notes and recommendations about various aspects or possible discovered problems. Reports in the project's forum were the only data collection tool used in this first stage.

In the second stage, called Beta testing, a sample of teachers was brought in to play the game and provide feedback about gameplay, mechanics and interaction with the game. In this stage, the data collection tools used was a questionnaire and a semi-structured interview. In the third and final stage, called Gamma testing, students were brought in to play the game and provide their feedback about it. This time, the data collection tools were two questionnaires, two knowledge tests, and a questionnaire to be answered by teachers.

In an attempt to apply the SELEAG methodology some problems occurred that compelled the evaluation methodology of this thesis to differ from the original one. At first, Alpha testing was excluded in the case of this thesis because there was only one person in the development team and evaluation by other irrelevant members was not possible. This means that the methodology was consisted of two stages, Beta and Gamma testing.

The normal sequence of these two testing methods would be to first use Beta testing, get the results, and fix any revealed problems before moving on to Gamma testing. In the case of this thesis though, unfortunately time deadlines forced the evaluation process to perform both stages at the same time.

In Beta testing, the museum staff played the game and each employee answered a questionnaire and a semi-structured interview, to provide their suggestions and general opinions about the game. In the second and final stage (Gamma Testing), our subject group played the game and answered two questionnaires and two knowledge tests, one of each pre and one post the game. The pre- and post-knowledge tests were identical. The museum expert (evaluation manager) that was in charge of the evaluation process answered a questionnaire to provide some extra data about the process. The two stages of the applied evaluation methodology are described in more detail in the following sub-sections.

5.2.1 Beta Testing

The aim of the first stage was to get the opinions and the suggestions of people who had the knowledge and experience to understand how the subject group could probably react in our game environment. At this stage, elements that had to do with the gameplay, the mechanics, and the interfaces of the game were mostly evaluated. During the first of the three weeks of the evaluation, the museum experts were asked to play the game and complete the questionnaire and interview at any time convenient for them. One of the museum experts was in charge of this operation.

5.2.1.1 Protocol - Sequence:

1. Participants' identification (Museum staff)
    a. Name, position, interests, e-mail
2. Game concept explanation
3. Participants had to play and try to win the game
4. Participants had to:
    a. Measure the time it took them to finish the whole game
    b. Answer the questionnaire
5. The participants were interviewed using a semi-structured interview

The whole process took place in a controlled environment for the participants to focus on the game and be able to provide as many opinions and suggestions as possible through their game experience.

5.2.1.2 Data Collection Tools

The data collections tools that were used for this stage were a questionnaire and a semi-structured interview. The questionnaire used in the first stage was the one shown in sub-section A1 of appendix A, where a Likert scale from 1 to 5 was applied to assess the game. The questionnaire is composed of 42 questions and it is divided into three sections: Gameplay, Game story, and Mechanics and Usability. So the total score of the questionnaire is 210. The semi-structured interview can also be found in appendix A, specifically in sub-section A2 and it consists of 13 questions.

5.2.2 Gamma Testing

The second and final stage of the evaluation process was performed with the end users. It was a complicated stage because it involved more users, users of various types and different data collection tools. Knowledge acquisition was evaluated by the comparative assessment of visitors' pre and post-game usage. Satisfaction was evaluated with the visitors and the museum experts.

5.2.2.1 Protocol - Sequence:

1. Identification of the museum in which the evaluation will be performed (information about the staff: name and subject of interest; information about visitors: age group and number).
2. Explanation of the testing procedure to the museum staff
    a. Visitors completed the first knowledge test and the motivation questionnaire to find out the current knowledge and motivations of each one.
    b. After the game, the visitors completed again the knowledge test and the satisfaction questionnaire to find out what they had learned and if they were satisfied with the game.
    c. Visitors were asked to give us their own opinion about the game.
    d. Museum staff answered their own questionnaire about the activity.

3. The testing was performed in the museum with each visitor taking turns to play the game on the tablet. Visitors were encouraged to help each other while playing the game.
4. The poll was completed before and after the gameplay.
5. Data collection (including information about the number of visitors, process problems, and game problems) was performed by the managing museum expert. It was also beneficial that the museum staff had played the game beforehand so they could help visitors if the help was needed.

5.2.2.2 Data Collection Tools

The data collection tools used in the second stage of evaluation was the questionnaires and knowledge test of sub-sections A3 to A5 of Appendix A. The knowledge test had one difference between the pre- and post-game situation. The pre-game knowledge test was composed of the first 10 questions that can be seen in the test, while in the post-game test the 11th question was added to check the impact of the information rooms and thus it was not graded. These 10 questions were designed to check every section of the learning goals of the game.

Each question of the knowledge test had a corresponding correct answer, and based on that answer the answers given by the subject group were graded. Each question had a top grade of 5 points, so the total score of the knowledge test was 50. The motivation questionnaire was comprised of 11 statements, on which the player was asked to evaluate depending on his/her agreement on a Likert scale of 1-7. This questionnaire was used to collect data about the profile of the player, and his/her perspective on his/her skills, interest, and motivations towards gaining knowledge about marble crafting. So the total score of the questionnaire was 77.

The satisfaction questionnaire was comprised of 19 statements, on which again the player was asked to evaluate depending on his/her agreement on a Likert scale of 1-7. This questionnaire was used to collect data about the satisfaction of the player after the game and it was divided into three sections: Interest, Skills, and Gameplay. The total score of the questionnaire was 133.

The final questionnaire was to be completed by the museum expert that was in charge of the evaluation process. It was composed of 6 questions divided into two sections: Satisfaction and Motivation, and Curriculum Integration. Just like before, the museum expert was asked to evaluate the statements depending on her agreement on a Likert scale of 1-5. As the museum expert was the only one that was present throughout the evaluation process and had the task of

observing the players' behavior before, during, and after the game, she was the only one that could provide the answers to the questions of this questionnaire. The total score of the questionnaire was 30.

Through observation of the children and the interactions between them, data were also collected regarding:

- Collaboration
- Gender groups
- Age groups

5.3 Reliability Analysis

For the questionnaires that were included in the evaluation process, a reliability analysis had to be performed. To that end the internal consistency of each of the three questionnaires was calculated. The Cronbach's Alpha coefficient should be above 0.7 so that the scale can be considered reliable with the sample. In the case of this thesis, the alpha coefficient was found 0.701 for the experts' questionnaire, 0.743 for the motivation questionnaire, and 0.416 for the satisfaction questionnaire. The internal consistency for the last questionnaire of the experts could not be calculated since it was completed by one person alone (the evaluation manager).

5.4 The Experiment

The evaluation period of MarbleGames was three weeks, starting from the 1st of August of 2015 and ending on the 22nd of August of 2015. The place in which the experiment was held was the museum for which the game was designed, which was the museum of marble crafts of Tinos. The android tablet on which the game was installed was placed in the cafeteria of the museum, at a table with many chairs around it, from which the player was facing the museum and its exhibits. A website was created for the online completion of the forms to be easily submitted. Online forms were available through the website for all data collection tools.

5.4.1 Evaluation Manager

In charge of the evaluation process was a museum staff member, who had the position of the Evaluation Manager (EM) for the evaluation experiment. The EM had the following tasks:

- Invite other museum staff members to participate in the Beta testing.
- Invite young visitors to participate in the Gamma testing.
- Provide help towards the participants whenever necessary during the game.
- Complete the questionnaires and interviews of the evaluation process for the participants and submit them through the website's forms.
- Complete the final questionnaire of Gamma testing.
- Observe the participants behavior during the game.

5.4.2 Beta Testing Experiment

The Beta testing took place only on the first week of the evaluation process (1-8 of August). The subject group of Beta testing was a group of four museum staff members. The EM invited them separately, introduced them to the game and explained the experiment to them. She let them play the game in the museum and then asked them to complete the questionnaire. Finally, she asked them if they wanted to complete the interview. Three of them agreed. The EM finally submitted the results of the questionnaires and interviews through the online forms.

5.4.3 Gamma Testing Experiment

The Gamma testing took place during the whole time period of the evaluation process. The subject group was a group of 26 children of ages 11-17. All of them were Greek. Half of them were males and half females.

During the three weeks of the evaluation process, if a child of that age was visiting the museum, the EM would ask the child (with is parents' permission), if he/she wanted to participate in the evaluation process and play the game. If the child responded positively, the EM would first provide him/her with the motivation questionnaire, and the knowledge test for completion. After completing the two forms, the child was allowed to play the game. During gameplay, the EM would assist if necessary while at the same time observing the child's behavior. If more than one child were present at the same time, collaboration was encouraged. When the child finished with

the game, the knowledge test and satisfaction questionnaire were completed by the child. All the forms were submitted online by the EM. At the end of the evaluation process period, the final questionnaire was completed and submitted by the EM.

5.4.3.1 Notes of the Evaluation Manager

After the evaluation process, the EM was asked to provide her notes and opinions about the whole process. She provided the following list:

- The children would often collaborate during gameplay. Often a competition was apparent between them.
- The game was about a 20 minutes lasting process.
- The questionnaire completion was about a 10-15 minutes lasting process.
- The amount of questionnaires that needed completion was a tiresome task for the children.
- Only six children won the game. All of them won sub-games 1-4, getting stuck at the 5th sub-game.
- There was one girl that completed all sub-games on the first try.
- Almost all children and museum experts had difficulty in winning the 5th sub-game.
- None of them gave up early.
- Immersion was created. For example, some of the children were moving along with the tools in the 2nd sub-game.
- The children did not get bored, they even replayed lost games, in some cases they replayed games they had already won.
- The most exciting sub-game for the children was the 2nd one.
- Parents often encouraged the children to participate in the evaluation and play the game.
- Only two families responded negatively to the invitation due to time limitations.
- Boys liked sub-games with tools most, while girls were usually more observant than boys.
- Children older than 12 usually read the instructions of the games, while smaller children did not.

Chapter 6
Analysis and Results

In an attempt to answer the questions set in the evaluation chapter of this thesis, analysis on the collected data was performed. Data were collected during the evaluation process which was divided in two stages: Beta testing, and Gamma testing. In Beta testing,, the data were collected by four museum experts who answered a post-game questionnaire regarding their opinion about the game. Three of the experts also took part in a semi-structured interview with the same goal, in order to accumulate qualitative data in addition to the quantitative data of the questionnaire.

In Gamma testing, the subject group was 26 children of ages 11-17, of which 13 were boys and 13 girls. All of them were Greek. The children of the subject group played the game and completed a motivation questionnaire and a knowledge test, both pre-game. The same knowledge test and a satisfaction questionnaire were completed post-game. Another questionnaire was completed by the EM at the evaluation period's end.

The analysis of the data was performed with the use of IBM's SPSS v22 program. The analysis as well as the results of the analysis for each stage of the evaluation process is presented in this Chapter.

6.1 Beta Testing

In this section the analysis and the results that were extracted from that analysis for the first stage of the evaluation process are presented.

6.1.1 Beta Testing Analysis

As mentioned above, Beta testing had only two data collection tools. The first one was the questionnaire, and the second one the semi-structured interview.

6.1.1.1 Beta Testing Questionnaire

All of the questionnaire's statements were positive with the exception of three of them which were negative. In the context of this thesis, a statement is regarded positive if its best score is 5 on the Likert scale 1-5 used in this case. On the other hand, a statement is regarded negative if its best score is 1 on the same scale. For example: "The game was fun" is a positive statement whereas "The game was too difficult" is a negative statement. To compensate for that difference, the points given by the experts on the three negative questions were reversed.

Table 6.1 shows the results of the questionnaire. The total score for four participants and 42 questions with highest points given for total agreement to a statement being 5 is 840. The score of the four participants is 576 of 840. Also, the mean for all the questions combined is 3.45 out of 5.

	Number of questions	**Questionnaire Mean**
Gameplay	15	0.62
Game Story	8	0.73
Mechanics and Usability	19	0.71
Total	42	0.69

Table 6.1: Beta testing questionnaire scores.

An example of the answers of the questionnaire can be seen from the following charts. Chart 6.1 shows the answers of the first three statements of the questionnaire.

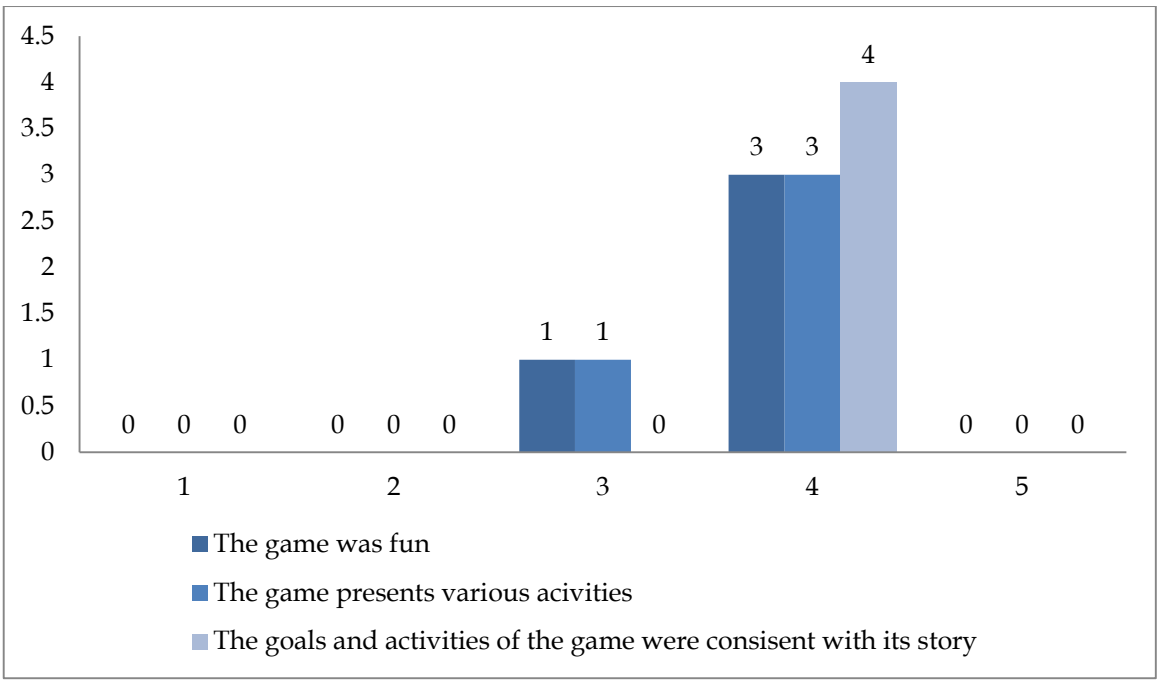


Chart 6.1: Scores of the first three statements of the Beta testing questionnaire.

Chart 6.2 shows the answers given by the four experts on the three negative questions, mentioned previously, before they were reversed.

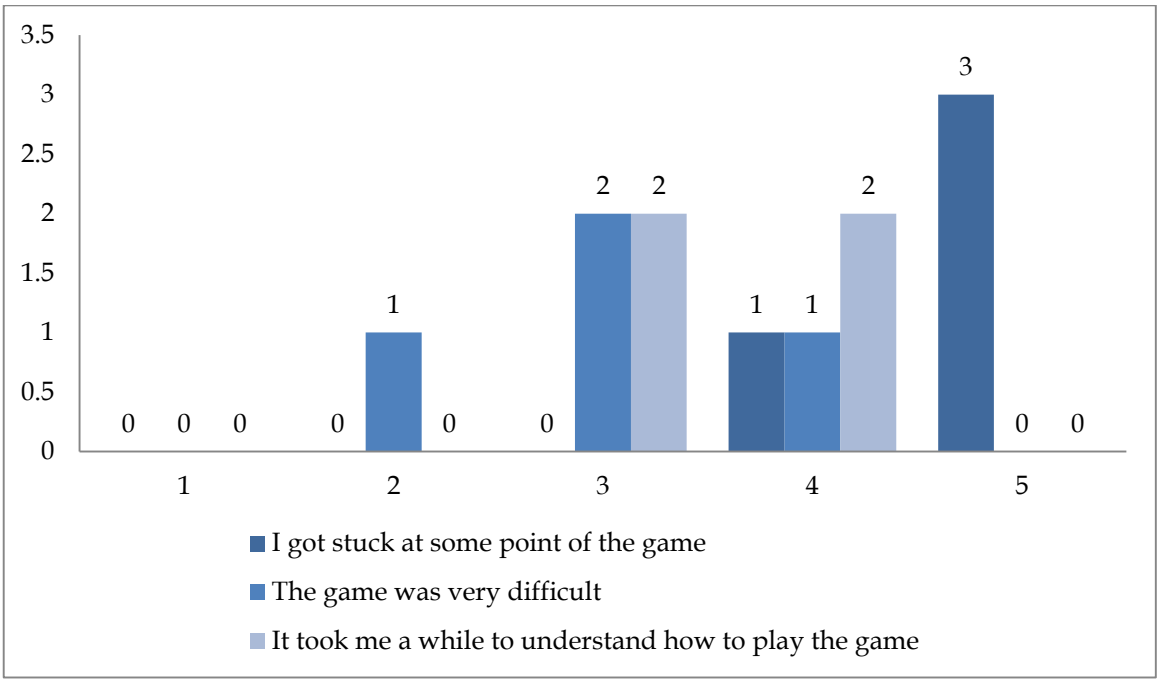


Chart 6.2: Scores of the three negative statements of the Beta testing questionnaire.

After the completion of the questionnaire, museum experts were asked if they had any comments for the game. Two of them responded.

1st Answer: *"Time was insufficient for both the 3D puzzle and the puzzle, which can be completed in time only when using the help option".*

2nd Answer: *"Having as a goal the evaluation of the game I would like to address some aspects. Specifically, in MarbleCreations I would like besides the icon, the name to be displayed as well (for convenience). SketchPuzzle game is difficult to complete in time without help. In MarbleCarvings bigger pieces could be removed because it could become tiresome for the children in the end. Lastly, GameOfMarbleThrone is too difficult and the time insufficient".*

6.1.1.2 Semi-Structured Interview

The semi-structured interview was composed of 13 questions and the number of participants was 3. Through content analysis on the three interviews the following notes were created:

- The game works.
- When there is more than one touch on the screen there is a problem.
- The content is accurate and appropriate for the target audience.
- Younger kids may have difficulties.
- A pre-game museum tour might be needed.
- The game is easy to use and easy to learn to use.
- One noted that there may be a need for an expert to show them how to play.
- The game is compelling and engaging for the target audience.
- Most entertaining games were found to be the MarbleExtractions and the SketchPuzzle. The least entertaining games were found to be the GameOfMarbleThrone and MarbleCarvings.
- The most educational game was found to be MarbleCreations. The least educational game was found to be GameOfMarbleThrone.
- Starting from the game they liked the most and ending at the game they liked the least, the following order was found: MarbleExtractions, SketchPuzzle, MarbleCreations, MarbleCarvings, and GameOfMarbleThrone.
- The learning goal of the game is for the children to understand what marble crafting is.
- Everyone agreed that the game achieves its own learning goals. One added that it also helps the player in getting to know the museum.

- The learning goals are achieved if enough interested is shown and if the children are in the age group for which the game was designed.
- They children also understand through the game, the difficulty and complexity of the marble crafting process.
- The game is quite complete in its curriculum. One mentions that the sketching stage should be amplified, while another notes that the game encourages visitors to learn more about the subject.
- Everyone agreed that the game can be used in an educational program, after a brief pre-game museum tour.

6.1.2 Beta Testing Results

In beta testing, two sets of data were collected. The first set was quantitative, while the second one was qualitative. From the questionnaire, it is easy to understand that the experts were mostly satisfied by the game, with a total score of 576/840, but they would prefer some issues to be addressed. This was exactly the point of the Beta testing: to identify and address some of the issues of the game. This was not possible due to insufficient time however, as mentioned before.

The advantage of this stage, is that it does not only informs of the percentage of which the participants are satisfied by the game (questionnaire), but it also provides valuable information about what it is that needs to be fixed with the use of the qualitative data (interview). So from the analysis of the Beta testing the most important elements that were gathered, regarding issues that should be addressed were:

- A pre-game museum tour could prove useful to the learning aspects of the thesis.
- Games that should be redesigned are GameOfMarbleThrone and possibly MarbleCarvings.

6.2 Gamma Testing

In this section the analysis and the results that were extracted from that analysis for the second stage of the evaluation process are presented.

6.2.1 Gamma Testing Analysis

Gamma testing data were collected with the use of three questionnaires and a knowledge test that was completed pre- and post-game.

6.2.1.1 Knowledge Test

The knowledge test contained questions set to evaluate if the learning goals of each sub-stage as defined earlier, were achieved. The pre-game test was used to grade the knowledge of each child of the subject group, while the post-game was used to evaluate if knowledge was gained through the game. Table 6.2 displays statistical information about the pre- and post-game tests.

	Pre-test	**Post-test**
N	**26**	**26**
Top score	**0.94** (47/50)	**0.95** (47.5/50)
Lowest score	**0.36** (18/50)	**0.61** (30.5/50)
Overall score	**0.68** (893.5/1300)	**0.83** (1090.5/1300)
Mean	**0.68** (34.36/50)	**0.83** (41.94/50)
Median	**0.73** (36.5/50)	**0.84** (42/50)
Std. Deviation	**8.638**	**3.953**
Std. Error Mean	**1.694**	**0.775**

Table 6.2: Statistical information about the knowledge test.

The difference between the scores of the pre- and post-game tests can also be seen graphically from chart 6.3.

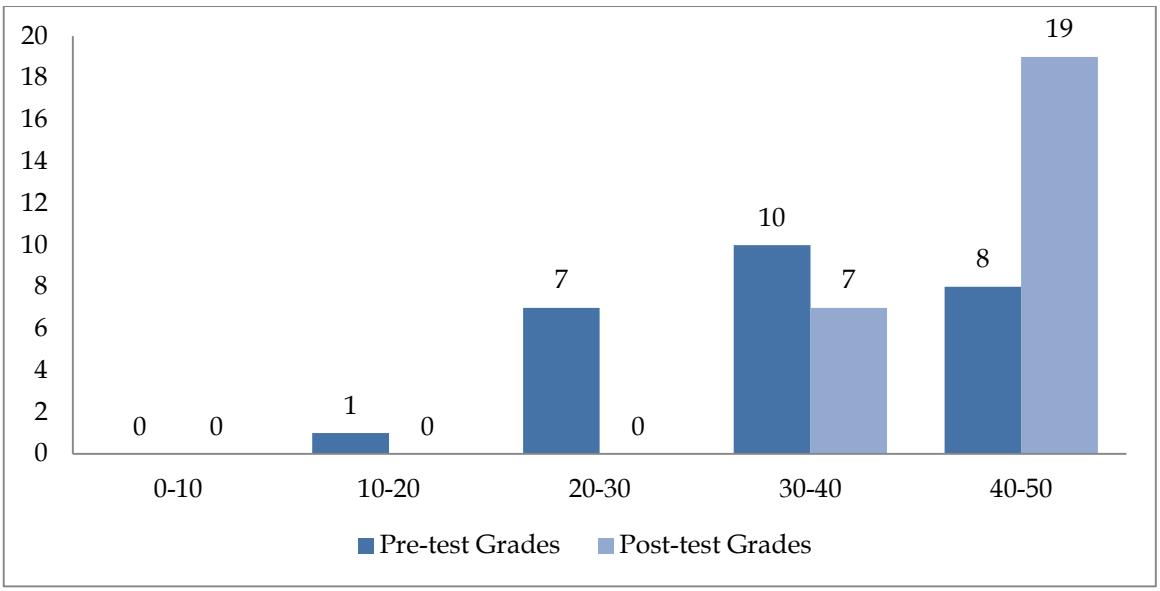


Chart 6.3: Comparison of the pre and post-test grades.

	Paired Differences					t	df	Sig. (2-tailed)
	Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
				Lower	Upper			
Pre and post tests	-7.576	8.198	1.607	-10.888	-4.265	-4.712	25	0.0

Table 6.3: Paired samples t-test results for the pre and post-test.

A paired-samples t-test was conducted to evaluate the difference between the scores of the pre-test and post-test. There was a statistically significant increase in scores from the pre-test (M = 34.36, SD = 8.638) to the post-test (M = 41.94, SD = 3.953), $t(25) = -4.712$, $p < 0.05$. The eta squared statistic (0.47) indicated a large effect size. The results of the samples t-test analysis can be seen in table 6.3.

Using independent samples T-test, and after dividing females (N=13) and males (N=13) of the subject group into two groups, a comparison of the two groups score means was performed. Important statistical information about the two groups can be seen in table 6.4.

		N	Mean	Std. Deviation	Std. Error Mean
Pre-test	**Males**	13	33.384	9.117	2.528
	Females	13	35.346	8.382	2.234
Post-test	**Males**	13	40.923	4.271	1.184
	Females	13	42.961	3.472	0.963

Table 6.4: Statistical information about the male and female group test grades.

		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
Pre-test	**Equal variances assumed**	0.574	0.467	-0.571	24	0.573	-1.961	3.435	-9.051	5.128
Post-test	**Equal variances assumed**	0.003	0.959	-1.335	24	0.194	-2.038	1.526	-5.189	1.112

Table 6.5: Independent samples t-test results for the male and female group test grades.

An independent-samples t-test was conducted to compare the pre-test scores for the males and females. There was no significant difference in scores for males (M =33.384, SD = 9.117) and females (M = 35.346, SD = 8.382), t(24) = -0.571, p = 0.573 > 0.05. The magnitude of the differences in the means was small (eta squared = 0.013). Another independent-samples t-test was conducted to compare the post-test scores for the males and females. Again no significant difference was discovered in the scores for males (M =40.923, SD = 4.271) and females (M = 42.961, SD = 3.472), t(24) = -1.335, p = 0.194 > 0.05. The magnitude of the differences in the means was moderate (eta squared = 0.069).

Another attempt to compare the means of two age groups was made with the same manner. An independent samples T-test was used to compare the means of an age group (U13) of ages under 13 (N=12), and an age group (A12) of ages of 13 and above (N=14). Important statistical information about the two groups can be seen in table 6.6.

		N	Mean	Std. Deviation	Std. Error Mean
Pre-test	**U13**	12	29.625	7.097	2.048
	A12	14	38.428	7.898	2.110
Post-test	**U13**	12	39.916	3.964	1.144
	A12	14	43.678	3.117	0.833

Table 6.6: Statistical information about the U12 and A13 group test grades.

		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
Pre-test	**Equal variances not assumed**	0.028	-0.869	-2.993	23.931	0.006	-8.803	2.941	-14.875	-2.731
Post-test	**Equal variances assumed**	0.091	0.766	-2.708	24	0.012	-3.761	1.389	-6.628	-0.895

Table 6.7: Independent samples t-test results for the U12 and A13 group test grades.

An independent-samples t-test was conducted to compare the pre-test scores for the U12 and A13 age groups. There was a significant difference in scores for U13 (M =29.625, SD = 7.097) and A12 (M = 38.428, SD = 7.898), t(23.931) = -2.993, p = 0.006 < 0.05. The magnitude of the differences in the means was large (eta squared = 0.27). Another independent-samples t-test was conducted to compare the post-test scores for the U12 and A13 age groups. Again, there was a significant difference in scores for U13 (M =39.916, SD = 3.964) and A12 (M = 43.678, SD = 3.117), t(24) = -2.708, p = 0.012 < 0.05. The magnitude of the differences in the means was large (eta squared = 0.23).

Since a significant difference between the two age groups was found, with the A12 group clearly performing better than the U13 group, a question arose as to whether the U13 age group's

achieved learning through the game was inferior to that of the A12 group. To answer that question a new paired samples t-test was performed for the U13 group alone.

	N	Mean	Std. Deviation	Std. Error Mean
Pre-test	12	29.625	7.097	2.048
Post-test	12	39.916	3.964	1.144

Table 6.8: Statistical information about the U12 group test grades.

	Paired Differences					t	df	Sig. (2-tailed)
	Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
				Lower	Upper			
Pre and post tests	-10.291	7.527	2.172	-15.074	-5.509	-4.736	11	0.001

Table 6.9: Paired samples t-test results for the pre and post-test for the U12 age group.

A paired-samples t-test was conducted to evaluate the difference between the scores of the pre-test and post-test for the U12 age group. There was a statistically significant increase in scores from the pre-test (M = 29.625, SD = 7.097) to the post-test (M = 39.916, SD = 3.964), $t(11) = -4.736$, $p = 0.001 < 0.05$. The eta squared statistic (0.67) indicated a large effect size.

The results of it clearly show that the learning is achieved for the U13 group with almost as much statistical difference as in the whole of the subject group with p-value = 0.001.

6.2.1.2 Motivation and Satisfaction Questionnaires

The motivation questionnaire which was completed pre-game, was used to give the participants the chance to provide their opinion regarding three aspects: Skills concerning marble crafting knowledge, interest about marble crafting, and motivation towards video games. The satisfaction questionnaire, which was completed post-game, was used to allow the participants describe their satisfaction by the game.

Just like in the case of the Beta testing questionnaire, all negative statement scores were reversed. Statistically significant information about the scores of the two questionnaires can be seen in table 6.10.

	Motivation Questionnaire	Satisfaction Questionnaire
N	**26**	**26**
Top score	**0.92** (71/77)	**0.84** (113/133)
Lowest score	**0.5** (39/77)	**0.63** (85/133)
Overall score	**0.71** (1438/2002)	**0.7** (2442/3458)
Mean	**0.71** (55.307/77)	**0.7** (93.923/133)
Median	**0.71** (55/77)	**0.69** (92.5/133)
Std. Deviation	**8.451**	**6.105**

Table 6.10: Statistical information about the motivation and satisfaction questionnaires' results.

To check the correlation between the motivation questionnaire and the satisfaction questionnaire, Pearson correlation was used.

		Motivation Questionnaire	Satisfaction Questionnaire
Motivation Questionnaire	**Pearson Correlation**	1	0.433
	Sig. (2-tailed)		0.027
Satisfaction Questionnaire	**Pearson Correlation**	0.433	1
	Sig. (2-tailed)	0.027	

Table 6.11: Pearson correlation for the motivation and satisfaction questionnaire results.

The relationship between the scores of the motivation questionnaire and the satisfaction questionnaire was investigated using Pearson product-moment correlation coefficient. Preliminary analyses were performed to ensure no violation of assumption of normality, linearity and homoscedasticity. There was a medium positive correlation between the two variables ($r=0.433$, $N = 26$, $p = 0.027 < 0.05$), with high levels of motivation associated with high levels of satisfaction. The two variables share 18.74% of their variance.

To examine the relationship between the opinions of the players regarding their skills, interests and motivations, with their final satisfaction, another correlation was checked between every section of the motivation questionnaire and the total satisfaction questionnaire.

	Motivation Questionnaire			Satisfaction Questionnaire
	Skills	**Interest**	**Motivation**	
N	**26**	**26**	**26**	**26**
Mean	**0.57** (12/21)	**0.83** (23.346/28)	**0.71** (19.961/28)	**0.7** (93.923/133)
Std. Deviation	**4.586**	**2.813**	**4.999**	**6.105**

Table 6.12: Statistical information about every section of the motivation questionnaire and the whole satisfaction questionnaire results.

In that regard, the Pearson correlation between each section's scores of the motivation questionnaire and the scores of the satisfaction questionnaire was calculated. The results can be seen in tables 6.13, 6.14, and 6.15.

		Satisfaction Questionnaire
Skills Section	**Pearson Correlation**	0.116
	Sig. (2-tailed)	0.574

Table 6.13: Pearson correlation between the skills section of the motivation questionnaire and the whole satisfaction questionnaire results.

The relationship between the scores of the skills section of the motivation questionnaire and the satisfaction questionnaire was investigated using Pearson product-moment correlation coefficient. Preliminary analyses were performed to ensure no violation of the assumptions of normality, linearity and homoscedasticity. There was a very small positive correlation between the two variables (r=0.116, N = 26, p = 0.574 > 0.05), with high levels of motivation associated with high levels of satisfaction. The two variables share 1.34% of their variance.

		Satisfaction Questionnaire
Interest Section	**Pearson Correlation**	0.363
	Sig. (2-tailed)	0.069

Table 6.14: Pearson correlation between the Interest section of the motivation questionnaire and the whole satisfaction questionnaire results.

The relationship between the scores of the interest section of the motivation questionnaire and the satisfaction questionnaire was investigated using Pearson product-moment correlation coefficient. Preliminary analyses were performed to ensure no violation of the assumptions of normality, linearity and

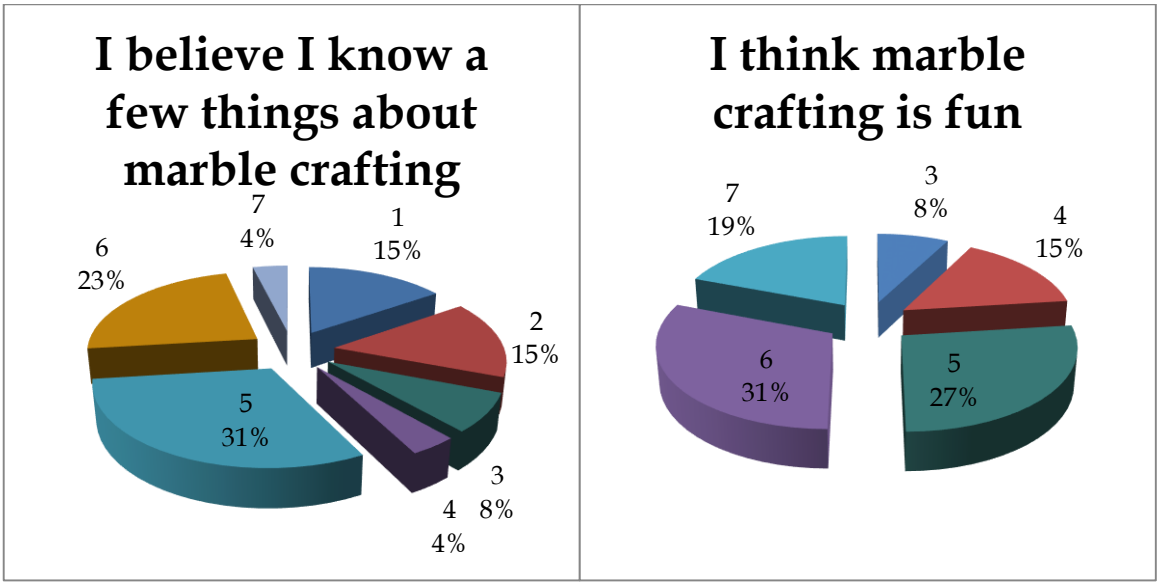
homoscedasticity. There was a medium positive correlation between the two variables (r=0.363, N = 26, p = 0.069 > 0.05), with high levels of motivation associated with high levels of satisfaction. The two variables share 13.17% of their variance.

		Satisfaction Questionnaire
Motivation Section	**Pearson Correlation**	0.422
	Sig. (2-tailed)	0.032

Table 6.15: Pearson correlation between the motivation section of the motivation questionnaire and the whole satisfaction questionnaire results.

The relationship between the scores of the motivation section of the motivation questionnaire and the satisfaction questionnaire was investigated using Pearson product-moment correlation coefficient. Preliminary analyses were performed to ensure no violation of the assumptions of normality, linearity and homoscedasticity. There was a medium positive correlation between the two variables (r=0.422, N = 26, p = 0.032 < 0.05), with high levels of motivation associated with high levels of satisfaction. The two variables share 17.8% of their variance.

It should be noted that the skills of the players is just the players' opinion of themselves and may not in fact be an objective result. The correlation was thus checked between that opinion and the final satisfaction. In charts 6.4, 6.5, and 6.6, the first statement of each section of the motivation questionnaire is shown with the responds of the subject group. The agreement Likert scale is 1-7, with 1 being total disagreement and 7 being total agreement.



Charts 6.4 and 6.5: 1st statement of the skills and interest sections of the motivation questionnaire results.

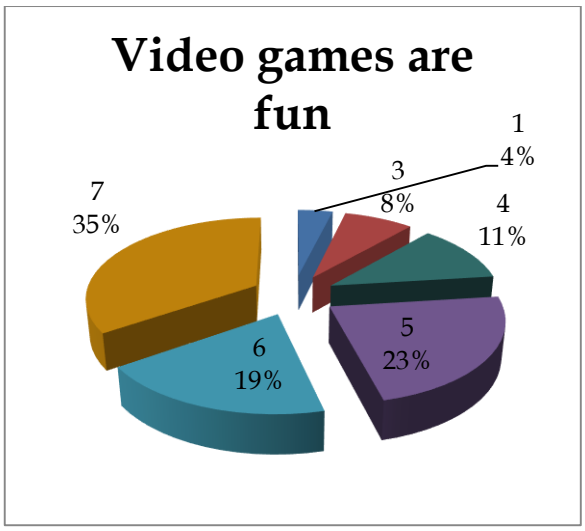


Chart 6.6: 1st statement of the motivation section of the motivation questionnaire results.

The final satisfaction of the subject's group can be seen graphically in chart 6.7. The total score of the satisfaction questionnaire for 19 questions and 26 participants is 133.

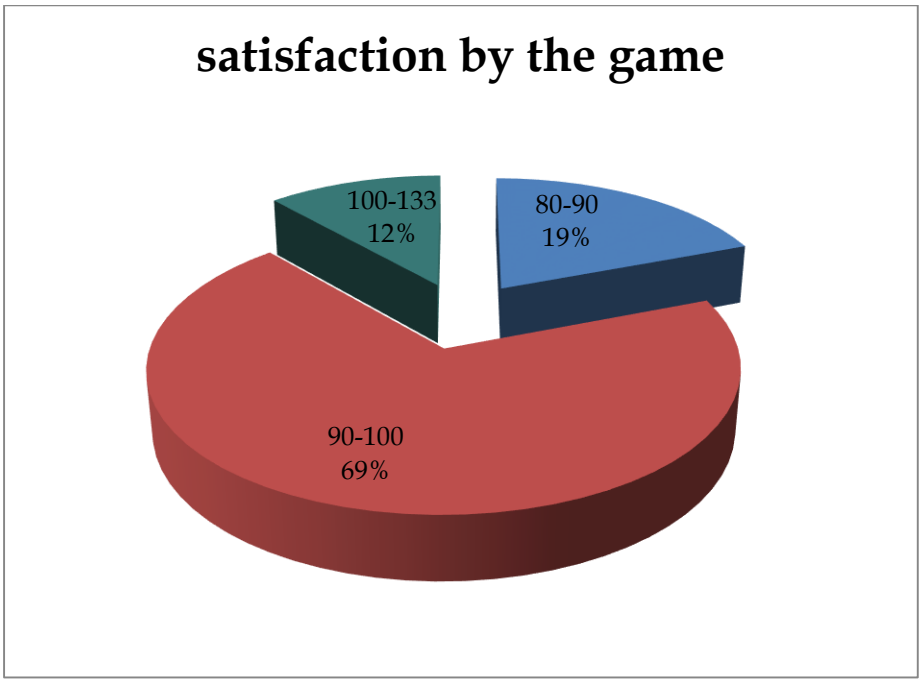
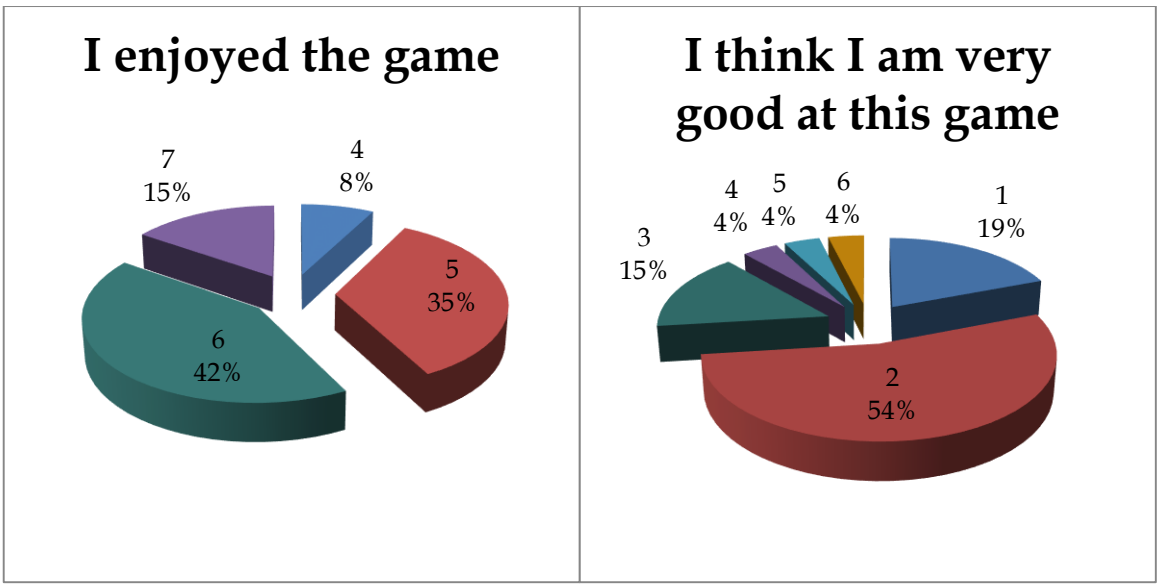


Chart 6.7: Final satisfaction of all players according to the satisfaction questionnaire results.

The score on the first statement of each section of the satisfaction questionnaire can be seen in charts 6.7, 6.8, and 6.9. The Likert scale used for the satisfaction questionnaire is the same as the one used in the motivation questionnaire.



Charts 6.8 and 6.9: 1st statement of the interest and skills sections of the satisfaction questionnaire results.

Chart 6.10: 1st statement of the gameplay section of the satisfaction questionnaire results.

6.2.1.3 Museum Expert's Questionnaire

The final data collection tool of the Gamma testing was a questionnaire completed by the EM. The EM's score can be seen in the following table.

Satisfaction and Motivation	
The visitors showed increased interest in the museum exhibits after playing the game.	5
Do you think their knowledge about the subject has increased?	4
Would you use this game in the museum again?	5
curriculum integration	
Has the game covered its subject's key points?	4

Were the subjects of the game comparable to those that the visitor would learn by a simple visit of the museum?	4
Do you agree that the game covers its learning goals?	5

Table 6.16: EM's questionnaire scores.

6.2.2 Gamma Testing Results

This section discusses the results of the final stage of the evaluation process and answers the four evaluation questions set in the empirical evaluation Chapter of this thesis.

6.2.2.1 Q1. Does the game increases the knowledge of the players about marble crafting?

The results were very clear in regard to this question. Just by viewing table 6.2, it is easy to realize that the scores of the post-test were increased significantly in relation to the scores of the pre-test. The lowest score has increased to 30.5 in the post-test in comparison to the 18 of the pre-test. Overall score has increased to 1090.5 in comparison to 893.5. The mean increased to 41.94 compared to the 34.36 of the pre-test. Median also increased from 36.5 to 42. Standard deviation is at 3.953 in comparison to the 8.638 of the pre-test.

As can be seen from table 6.3, the conducted paired samples T-test indicated that there is a statistically significant increase between the scores of the pre-test and post-test ($M = 41.94$, $SD = 3.95$), $t(25) = -4.712$, $p < 0.05$. The eta squared statistic (0.47) indicated a large effect size. All of the above lead to answering the question positively, as the findings indicate that the knowledge of the players has increased by the game.

6.2.2.2 Q 2. Do female players achieve more learning than male players?

This question was added in the evaluation questions set after taking into consideration the following observation of the EM: "Boys liked sub-games with tools most, while girls were usually more observant than boys".

In order to provide an answer to that question, an independent-samples t-test was conducted to compare the pre and post-tests' scores for the males and females. There was no significant difference in the scores for males and females as it can be seen from table 6.5. That answers the question negatively, since through the findings of this thesis, it is shown that the gender of the player does not affect the learning achieved by the game.

6.2.2.3 Q 3. Do older players achieve more learning than younger players?

This question was also added in the evaluation questions set after taking into consideration the following observation of the EM: "Children older than 12 usually read the instructions of the games, while smaller children did not".

Just like in the case of male and female groups, another comparison of the means of two groups (A12 and U13), was performed to answer the third question. According to the calculated p-value there was a statistically significant difference between the scores of the two age groups. The results of the conducted independent-samples t-test for the comparison of the means of the scores for the two groups on both pre and post-tests can be seen in table 6.7. The magnitude of the differences in the means was large (eta squared: Pre-test = 0.27, Post-test = 0.23).

To further examine the impact of that difference, another paired samples t-test was calculated for the U13 group alone. The results of it clearly indicated that the learning was achieved for the U13 group with almost as much statistical difference as in the whole of the subject group with p-value = 0.001. The p-value of the whole subject group was < 0.005. The results of the paired-samples t-test can be seen in table 6.9.

To answer the question: According to the findings of the thesis, the age of the player is affecting the learning achieved by the game. The age group for which the game was designed (13-17) performed better than younger kids (11-12). Despite that fact, younger kids also achieve quite a similar learning through the game.

6.2.2.4 Q 4. Is there a relationship between the initial motivation of the player and his/hers final satisfaction?

This question was included in the evaluation questions set to help answer the second research question: "Can a video game enrich the experience for museum visitors of ages 13 to 17?"

To answer that question the relationship between the scores of the motivation questionnaire and the satisfaction questionnaire was investigated using Pearson product-moment correlation coefficient. There was a medium positive correlation between the two variables ($r=0.433$, $N = 26$, $p = 0.027 < 0.05$), with high levels of motivation associated with high levels of satisfaction. The two variables share 18.74% of their variance. That means that by obtaining the scores of the

motivation questionnaire we can predict to a percentage of 18.74% the scores of the satisfaction questionnaire. The results of the correlation can be seen in table 6.11.

These findings answer the question by indicating that the satisfaction of the player by the game is partly affect by the player's initial motivation. Further analysis however, indicated that interest and motivation were medium positively correlated to the satisfaction of the player, whereas the player's opinion of his/her shills had very small correlation to his/her final satisfaction by the gaming experience. These results can be seen in tables 6.13, 6.14, and 6.15.

Chapter 7
Epilogue

This thesis aim was to develop a learning game for the museum of marble crafts of Tinos, which would enable its younger visitors, to learn more about marble crafting just by playing the game. Another aim of the game was to assist the players become more interested in the whole idea of marble crafting and in the exhibits of the museum in general. The target group of the developed game was chosen to contain children of ages 13-17, as families and groups with children were found to be among the most common museum goers [45].

The design of the game was mostly based on Gagne's nine events of instruction [17], as restructured by Gunter et al. [21]. Guidance was also taken by a Serious Game Design Tutorial [49]. The game was implemented using the unity game engine to develop a game that was consisted of 2D and 3D worlds combined. It was composed of a set of five sub-games of the following types: puzzle, memory, quiz, and tabbing.

An existing evaluation methodology [43] was modified in order to evaluate the developed game. Four evaluation questions were answered by the results of the analysis. These answers based on the results of this thesis were:

1. The game does manage to increase the knowledge of the player about marble crafting.

2. Achieved learning is not dependent on the gender of the player.

3. Achieved learning is slightly dependent on the age of the player.

    a. Younger kids had also gained new knowledge by the game but performed slightly worse on the knowledge tests than the target group of the developed game. These findings are in agreement with the statements related with age factors as expressed in the case of the Kurio project [53].

4. The satisfaction of the player by the game is mostly associated to his/her initial interest in the subject, and his/hers motivations towards the video game itself. This can be linked to Bloom's [05] argument that everyone is capable of learning if enough interest and motivation exists.

    a. Only a small association was found between the opinion of the player about his/her skills of the subject and his/her final satisfaction by the game.

From the observations of the EM and further results of the thesis the following can also be concluded:

- The visitors showed increased interest in the museum exhibits after playing the game.

- Children were very satisfied by the game.

From the observation of the subject group while playing the game, the following notes were gathered:

<u>Positive notes:</u>

The children would often collaborate during gameplay. Often a competition was apparent between them. The game was about a 20 minutes lasting process. None of them gave up early. Immersion was created. For example, some of the children were moving along with the tools in the 2nd sub-game. The children did not get bored, they even replayed lost games. In some cases

they replayed games they had already won. The most exciting sub-game for the children was the 2nd one.

All of the above were intended by the game. 15 to 20 minutes was exactly the time limit for which the game was designed, cooperation between the players was encouraged, and immersion is obviously great for any game.

Negative notes:

Only six children won the game. All of them won sub-games 1-4, getting stuck at the 5th sub-game. Almost all children and museum experts had difficulty in winning the 5th sub-game. Children older than 12 usually read the instructions of the games while smaller children did not. The problem with the 5th game was apparent from the results of this thesis. For example, only one girl managed to complete all sub-games from the first try out of the 26 children.

The research questions asked in the introduction of this thesis were answered through the whole thesis and its results:

1. Learning about a museum's topic can be achieved for museum visitors of ages 13 to 17, and even younger children, through a video game, according to the findings of this thesis.

2. A video game can enrich the experience for museum visitors of ages 13 to 17, and even younger children, according to the findings of this thesis.

The four axes of importance were also addressed, as can be seen from the findings of this thesis:

- Promotion of museum exhibits through the game.

- Acquire new knowledge about the museum and its subject.

- Enhancement of the museum visitors' experience.

- Raise the awareness of peripheral museums in including new technologies.

Exhibits were promoted by letting the players interact with them through the game, new knowledge was obviously gained as can be seen from the results of the thesis, the visitors'

experience from the museum was enhanced as it can be seen from the satisfaction questionnaire results, and lastly, the awareness of the peripheral museum was raised, since the museum asked for extending the collaboration and maintaining the game at its grounds.

Constraints:

The thesis naturally had its own constraints which are listed here:

- The developer of the game could not participate in the evaluation process due to distance limitations.
- There was only one person in charge of the evaluation process.
- There was only one person for the grading of the questionnaires and knowledge tests.
- Beta testing subject group was small.
- Beta testing and Gamma testing took place at the same time.
- Gamma testing subject group was composed of only Greek citizens.

Future Work:

It is apparent that there were also problems besides the fact that the game achieved its learning goals. Future work would entail the redesign of the 5th sub-game, and possibly the 3rd to provide more learning and entertainment through them. Due to the non-existing intention of younger children to read the instructions of the game, an easier version of the game could be developed, giving the choice for the player to select the game's difficulty from the start.

Collaboration with the museum will be a high priority, in order to achieve the best possible results for the game, the museum, and its visitors. In a final note, it is the author's opinion that this thesis with the presented findings could lead to bigger and better equipped projects with even greater learning results in a variety of cultural sites and for various age groups.

References

[01] Abt, C., C. 1970, "Serious Games", University Press of America.

[02] Antle, A.N. 2007, "The CTI framework: informing the design of tangible systems for children", In: Proc. of the 1st International Conference on Tangible and Embedded Interaction, TEI 2007, pp. 195–202. ACM 2007.

[03] Beck, K., Beedle, M., van Bennekum, A., Cockburn, A., Cunningham, W., Fowler, M. et al. 2001, "Manifesto for agile software development", Available in: http://www.agilemanifesto.org, Accessed 04/15.

[04] Blomberg, J., Giacomi, J., Mosher, A. & Swenton-Wall, P. 1993, "Ethnographic Field Methods and Their Relation to Design", In D. Dchuler and A. Namioka (Eds.) Participatory Design: Principles and Practices, Erlbaum, New Jersey, 123 -155.

[05] Bloom, B. S. 1956, "Taxonomy of Educational Objectives, Handbook I: The Cognitive Domain", New York: David McKay Co Inc.

[06] Cabrera, J. S., Frutos, H. M., Adrian, G. S., Avouris, N., Dimitriadis,Y., Fiotakis, G. & Liveri, K. D. 2005, "Mystery in the Museum: Collaborative Learning Activities Using Handheld Devices", Paper presented at the 7th International Conference on Human Computer Interaction with Mobile Devices & Services, September 19-22, 2005, Salzburg, Austria.

[07] Cowley, B., et al. 2014, "Learning When Serious: Psychophysiological Evaluation of a Technology-Enhanced Learning Game", Journal of Educational Technology & Society 17.1 (2014): 3-16.

[08] Damasio, A.R. 1995, "Descarte's Error: Emotion, Reason, and the Human Brain", Harper Perennial.

[09] Dempsey, J., V. & Johnson, R., B. 1998, "The Development of an ARCS Gaming Scale", Journal of Instructional Psychology, 25 (4), 215-221.

[10] De Freitas, S. & Jarvis, S. 2006, "A Framework for Developing Serious Games to meet Learner Needs", Interservise/Industry Training, Simulation and Education Conference (I/ITSEC), Florida.

[11] De Freitas, S. & Oliver, M. 2005, "A four dimensional framework for the evaluation and assessment of educational games", Computer Assisted Learning Conference.

[12] Ferrara, J. 2012, "Playful Design. Creating Game Experiences in Everyday Interfaces", Rosenfeld Media, New York.

[13] Fisher, S. 2005, "An Evaluation of Learning On the Move and Science Navigator: Using PDAs In Museum, Heritage and Science Centre Settings", Nesta Report.

[14] Flanagan, M. 2009, "Critical Play: Radical Game Design", MIT Press. Cambridge.

[15] Frochauer, J., Seidel, I., Gartner, M., Berger, H. & Merkl, D. 2010, "Design and evaluation of a serious game for immersive cultural training", 16th International Conference on Virtual Systems and Multimedia (VSMM), 2010, 253-260.

[16] Fuller, G.R. 2003, "Don't tell me, I'll find out", Robert Karplus – a science education pioneer, Journal of Science Education and Technology, 12, 4 (2003), 359-369.

[17] Gagne, R. 1985, "The Conditions of Learning (4th ed.)". New York: Holt, Rinehart & Winston.

[18] Garrett, J. J. 2002, "The elements of user experience: User-centered design for the Web", Indianapolis, IN: New Riders, p. 21.

[19] Gee, J. 2003, "What Video Games Have to Teach Us about Learning and Literacy", New York: Palgrave McMillan.

[20] Gee, J. 2005, "Why Video Games are Good for Your Soul: Pleasure and Learning", Victoria, Australia: Common Ground.

[21] Gunter G., Kenny R. F. & Vick E. H. 2006, "A Case for Formal Design Paradigm for Serious Games", The Journal of the International Digital Media and Arts Association 3.1: 93-105.

[22] Hornecker, E. 2008, "I Don't Understand it Either, but It Is Cool", Visitor Interaction with a Multi-Touch Table in a Museum. Proceedings of the 2008 Tabletop: 121-128.

[23] Hornecker, E. & Buur, J. 2006, "Getting a grip on tangible interaction: a framework on physical space and social interaction". In: Proc. CHI 2006, pp. 437–446. ACM 2006.

[24] Hsi, S. 2004, "I-Guides in progress: Two prototype applications for museum educators and visitors", In Proceedings of the 2nd IEEEWMTE2004. J. Roschelle, T.W. Chan, Kinshuk, S.Yang (Eds). IEEE Press, pp.187-192. New York: IEEE Press.

[25] Hsi., S. 2003, "The Electronic Guidebook: A Study of User Experiences Mediated by Nomadic Web Content in a Museum Setting", Journal of Computer-Assisted Learning, vol. 19, no 3 (September): 308–319.

[26] Iza, M.S., Sebastien, G. & Franck, T.B. 2014, "Evaluating Learning Games during their Conception", Proceedings of the European Conference on Game Based Learning ECGBL. 9-10 October 2014, Berlin, Germany, pp. 364-371.

[27] Jackson, B. 1998, "Evaluation of learning technology implementation VALUE views activities and learning: Understanding evaluation", Edinburgh: Learning Technology Dissemination Initiative.

[28] Jacucci, G., Morrison, A., Richard, G. T., Kleimola, J., Peltonen, P., Parisi, L. & Laitinen, T. 2010, "Words of Information: Designing for Engagement at a Public Multi-Touch Display", Proceedings of the 2010 CHI: 2267-2276.

[29] Keller, J. M. 1983, "Motivational Design of Instruction", In Reiguluth C. M. (ed), Instructional Design Theories and Models: An Overview of Their Current Status, New York: Lawrence Erlbaum, 383-434.

[30] Kelman, I. 1995, "Responsive Evaluation in Museum Education", In E. Hooper-Greenhill (Ed.), Museum, media, message. London: Routledge.

[31] Klopfer, E., et al. 2005, "Mystery at the museum: a collaborative game for museum education", Proc. CSCL 2005, ACM Press (2005), 316-320.

[32] Laurel, B. 1990, "The Art of Human Computer Interface Design", USA: Addison- Wesley Publishing Company, USA.

[33] Le Hong, S. & Biesterfeldt, J. 2010, "A cultural touch - Study analyzing cultural differences and similarities in gesture-based operation of multi-touch interfaces", Publication by User Interface Design GmbH.

[34] Marshall, P., Morris, R., Rogers, Y., Kreitmayer, S. & Davies, M. 2011, "Rethinking 'Multiuser': An in-the-wild Study of How Groups Approach a Walk-Up –and-Use Tabletop Interface", Proceedings of the 2011 CHI: 3033-3042. 2011.

[35] Meek, J. 2006, "Adopting a lifecycle approach to the evaluation of computers and information technology", PhD Thesis. School of Electronic, Electrical and Computer Engineering, University of Birmingham.

[36] Mitgutsch, K., & Narda, A. 2012. "Purposeful by Design? A Serious Game Design Assessment Framework", Proceedings of the International Conference on the foundations of digital games, ACM, 2012.

[37] Mortara, M., et al. 2014, "Evaluating the Effectiveness of Serious Games for Cultural Awareness: the Icura User Study", Games and Learning Alliance Springer International Publishing, 2014, 276-289.

[38] National Research Council. 2000, "How People Learn: Brain, Mind, Experience, and School", The National Academies Press. Washington, USA.

[39] Nobre V. M., Haguenauer, C. J., Cunha, G. G. & Cordeiro Filho, F. 2011, "Learning in Museums with Use of Digital Technologies and Virtual Reality", Virtual Reality, 1(1), 13-27.

[40] Patsoule, E. 2014, "Interactions around a Multi-touch Tabletop: A Rapid Ethnography Study in a Museum", In: Third International Conference, DUXU 2014, Held as Part of HCI International 2014, Heraklion, Crete, Greece, June 22-27, 2014, Proceedings, Part IV, pp 434-445.

[41] Reynolds, R., Walker, K. & Speight, C. 2010, "Web-based museum trails on PDAs for university-level design students: Design and evaluation", Computers and Education, 55 (3), 994-1003.

[42] Rollings, A. & Adams, E. 2003, "Andrew Rollings and Ernest Adams on Game Design", Indianapolis, IN: New Riders.

[43] Rugeji, J., Sillaots, M. & Vaz de Carvalho, C. 2001, "SELEAG Evaluation Methodology", Implementation report, Available in: http://legacy.seriousgamesnet.eu/file/view/1856/evaluationmethodologydocx, Accessed: 06/15.

[44] Ryall, K., Morris, M., Everitt, K., Forlines, C., & Shen, C. 2006, "Experiences with and observations of direct touch tabletops", Proceedings of the 2006 IEEE TableTop the International Workshop on Horizontal Interactive Human Computer Systems: 89 - 96.

[45] Sabbatini, M. 2003, "Museums and virtual science centers: a new frontier for the scientific culture", Available in: http://www.comciencia.br/reportagens/cultura/cultura14.shtml, Accessed 04/15.

[46] Santos, N. 2003. "Interfaces of Educational Environments: Design Guidelines", Available in http://www.ime.uerj.br/professores/neidenew/Interfaces.htm. Accessed 07/2003.

[47] Sharlin, E., Watson, B., Kitamura, Y., Kishino, F. & Itoh, Y. 2004, "On tangible user interfaces, humans and spatiality". Personal and Ubiquitous Computing 8, 338–346.

[48] Shreeve, J. 2005, "Let the Games Begin". Edutopia. Available in: http://www.edutopia.org/magazine/ed1article.php?id=art_1286&issue=apr_05#, Accessed 07/12.

[49] Talib, H. 2012, "Serious Game Design Tutorial", [PowerPoint slides].

[50] Van Dijk, E. M. A. G., van der Sluis, F. & Nijholt, A. 2012, "Designing a museum multi-touch table for children". In Proceedings of the 4th International ICST Conference on Intelligent Technologies for Interactive Entertainment (INTETAIN'11). A. Camurri and C. Costa Eds., Lecture Notes of the Institute for Computer Sciences, Social-Informatics and Telecommunications Engineering, vol. 78, Springer, 139–148.

[51] Vavoula, G. & Sharples, M. 2009, "Challenges in evaluating mobile learning", International Journal of Mobile and Blended Learning, 1(2).

[52] Vavoula, G., Sharples, M., Rudman, P., Meek, J. & Lonsdale, P. 2009, "Myartspace: Design and evaluation of support for learning with multimedia phones between classrooms and museums", Computers and Education, 53(2), 286–299.

[53] Wakkary, R., Hatala, M., Muise, K., Tanenbaum, K., Corness, G., Mohabbati, B., et al. 2009. "Kurio: A museum guide for families", TEI '09: Proceedings of the 3rd International Conference on Tangible and Embedded Interaction, Cambridge, United Kingdom, 2009, p. 215-22.

[54] Winn, M., B. 2008, "The Design, Play, and Experience Framework", Handbook of research on effective electronic gaming in education 3: 1010-1024.

[55] Wishart, J. & Triggs, P. 2010, "MuseumScouts: Exploring how schools, museums and interactive technologies can work together to support learning", Computers & education 54, pp. 669–678.

[56] Yatani, K., Sugimoto M. & Kusunoki F. 2004, "Mugender: a system for supporting children's collaborative learning in a museum with PDAs", WMTE 2004: Proceedings of the 2nd IEEE International Workshop on Wireless and Mobile Technologies in Education.

Appendix A
Interview, Questionnaire and Test Forms

In the following sub-sections there are given: the interview, questionnaire, and test forms used during the evaluation methodology of this thesis.

A.1 Questionnaire for Museum Staff – First Stage

Please complete the following questionnaire according to the agreement table.

Stand	Total Disagreement	Disagreement	Neutral	Agreement	Total Agreement
Rating	1	2	3	4	5

Questionnaire for the Museum Experts – 1st Evaluation Stage	
GAME PLAY	
1. The game was fun	
2. The game presents various activities	
3. The goals and activities of the game were consistent with its story	

4. The final goal of the game was presented early in the game	
5. The goals of the game were clear throughout the game	
6. The game was fun to replay	
7. There are various ways to win the game	
8. The player learns as the game moves forward	
9. The player can deviate from the main goal of the game to view some extra information	
10. I got stuck at some point of the game	
11. The consequences of the player actions can be seen clearly in the game environment	
12. The rhythm of the game was satisfactory	
13. The game was too easy	
14. The game was very difficult	
15. The game offered a good challenge	
GAME STORY	
16. Game story was clear	
17. Game story was interesting	
18. Game story was relevant to the goal of the game	
19. The results of the player actions were fair	
20. The sound in the game help immerse the player in the game	
21. The graphics of the game help immerse the player in the game	
22. The game offers sufficient rewards for the players successful actions	
23. The player can relate to the main character	
MECHANICS AND USABILITY	
24. Audio and visual feedback is provided with each player's action	
25. The game behaves as the player expect it to	
26. The player is informed of the game progress throughout the game	
27. The controls of the game were easy to use and intuitive	
28. The game uses a familiar control system	
29. The player can enter and exit the game easily	
30. The controls were the same throughout the game	
31. The colors of the game were consisted throughout the game	

32. Fonts and dialogues of the game were consisted throughout the game	
33. Game menu was easily accessed	
34. Game menu was easy to understand	
35. Upon initially turning the game on the player has enough information to start playing the game	
36. The help elements of the game were sufficient	
37. The help elements of the game were as helpful as they should be	
38. The player can play the game without reading the manual	
39. The interface of the game was non-intrusive to the player	
40. It took me a while to understand how to play the game	
41. The guides of the game were clear and helpful	
42. The graphics of the game were recognizable to the players and it was clear what items were by looking at them	

Information About Museum Expert	
Full name	
Museum position / interests	
Email	

Extra Notes

A2. Semi-Structured Interview

Interview for the Museum Experts – 1st Evaluation Stage
Does it work?
Is the content accurate and appropriate for the target audience?
Is it easy to use and learn to use?
Is it compelling / engaging for the target audience?
Which of the five games do you find more entertaining and which the least?
Which of the five games do you think it teaches the most things and which the least?
Put in an order the five games starting with your favorite and ending with your least favorite.
What are the learning goals?
After the participant identifies what students can learn from the game, present the expected learning outcomes and see if he/she agrees.
How well do the learners achieve these goals?
What else are they learning?
What else should they be learning?
How could this game be used in the museum?
Notes:

Suggestions:

- Have a tape recorder in advance

- Conduct the interview in a quiet location
- Ask for permission to use the recorder
- Take auxiliary notes if necessary

Information About Museum Expert	
Full name	
Museum position / interests	
Email	

Extra Notes

A3. Motivation Questionnaire

For each of the following statements, choose their validity.

Is it Valid?	Not at all	I think so	A little	Neutral	It is	A lot	Absolutely
Rating	1	2	3	4	5	6	7

Motivation Questionnaire For Museum Visitors – 2nd Evaluation Stage	
SKILLS	
I believe I know a few things about marble crafting	
I know more things about marble crafting than most people	
I am satisfied with my current knowledge of marble crafting	
INTEREST	
I think marble crafting is fun	
I think marble crafting is interesting	
I think marble crafting is a pleasant subject	
I think marble crafting is boring	
MOTIVATION	
Video games are fun	

I play video games often	
I can easily obtain new knowledge from video games	
When a problem presents while I play a game I try to solve it by my self	

Information About Museum Visitor	
Full name	
Age	
Gender	
Country of origin	

Extra Notes

A4. Knowledge Test

2nd Knowledge Test For Museum Visitors – 2nd Evaluation Stage
1. Write a brief general description of what you think marble crafting is.
2. Write some of the stages of marble crafting.
3. Which of the following tools is used during the marble extraction stage?
a Spoon – Koutalaki b Fagana c Stela d Lama
4. Which of the following are marble extraction techniques?
a Rapina b Fournelo & wedges c Calcite & dolomite d Veloni & fagana
5. Which of the following are main elements of marble?
a Stalactite & flint b Sodium & stannum

c Calcite & dolomite d Chlorite & potassium
6. What is usually the final stage of marble crafting?
7. At which stage of marble crafting is the “Veloni” tool mostly used?
a Sketching - Drawing b Karaiskaki c Carving d Milling
8. In which technique is gun powder used?
a Wedge b Scratcher c Fournelo d Thyme
9. Which stage is usually the previous one of the carving stage?
a Sketching - Drawing b Extraction c Assembly d Transport
10. Choose and number the carving tools starting with the tool that is first used.
a◯ Fagana, Veloni & lama b◯ Bikouni, ball & thrapina c◯ Matrakas, chisels & spoon - koutalaki d◯ Ksilogaidoura, sledgehammer & veloni
11. Do you remember anything from the information rooms? If so please write about it.

Information About Museum Visitor	
Full name	
Age	
Gender	
Country of origin	

Extra Notes

A5. Satisfaction Questionnaire

For each of the following statements, choose their validity.

Is it Valid?	Not at all	I think so	A little	Neutral	It is	A lot	Absolutely
Rating	1	2	3	4	5	6	7

Satisfaction Questionnaire For Museum Visitors – 2nd Evaluation Stage	
INTEREST	
I enjoyed the game	
The game was fun	
The game was boring	
I wasn't focused on the game	
The game is very interesting	
The game is entertaining	
During the game I was thinking how much fun I was having	
SKILLS	
I think I am very good at this game	
I think I did good at this game compared to other players	
After playing for some time I think I got very good at it	
I am satisfied with my game performance	
I am very skilled at this game	
GAME PLAY	
I had fun learning from this game	
I could identify myself with the main character	
After the game I can comprehend better what marble crafting is	
I had enough information about how to play the game on game start	
It took me a while to figure out how to play the game	
There was enough feedback to let me know what I did wrong during the game and I was able to do it correctly the second time	
I think I have learned some things about marble crafting by playing this game	

Information About Museum Visitor	
Full name	
Age	

Gender	
Country of origin	

Extra Notes

A6. Questionnaire for Museum Staff – Second Stage

Please complete the following questionnaire according to the agreement table.

Stand	Total Disagreement	Disagreement	Neutral	Agreement	Total Agreement
Rating	1	2	3	4	5

Questionnaire for the Museum Experts – 2nd Evaluation Stage	
SATISFACTION AND MOTIVATION	
The visitors showed increased interest in the museum exhibits after playing the game.	
Do you think their knowledge about the subject has increased?	
Would you use this game in the museum again?	
CURRICULUM INTEGRATION	
Has the game covered its subject's key points?	
Were the subjects of the game comparable to those that the visitor would learn by a simple visit of the museum?	
Do you agree that the game covers its learning goals?	

Information About Museum Expert	
Full name	
Museum position / interests	

Extra Notes