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musARum - A game based system for promoting reflective learning

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Abstract

The main focus in this thesis was to develop a technological tool to make learning more fun, and to enable the students to reflect on their performance after partaking in an activity. In particular the main goals are: 1. Promoting an engaging user experience during a museum visit using mobile augmented reality. 2. Enabling students to reflect on their experience. Design choices were made on the basis of available theory, literature, and similar systems supporting reflection. The system was evaluated through usability testing, an expert evaluation, and a user evaluation in a realistic environment. The user evaluation turned out to be great success with more than 50 participants, and very few issues with the system itself.

The work resulted in a mobile application utilizing augmented reality to engage students in a collaborative quiz, and a web-application which presents users with data collected during the activity to help them reflect on their experience and learn from it.

This thesis, the developed system, and its evaluation contribute with an increased understanding of how technology can be used to promote reflection with young learners in order to improve their learning abilities.

Preface

This thesis is submitted to the Norwegian University of Science and Technology for partial fulfillment of the requirements for a master's degree. This work has been performed at the Department of Computer and Information Science, NTNU, Trondheim. The work was supervised by Professor Monica Divitini and co-supervised by Dr. Ines Di Loreto. It build on the work done in the autumn of 2013 during the Computer Science, Specialization Project TDT4501.

I would like to thank my supervisors for their valuable feedback and guidance throughout the project, as well as the participants that volunteered to evaluate my system.

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Chapter 1

Introduction

This thesis is a continuation of the work that was done during TDT4501 Computer Science, specialization project the fall of 2013. The purpose of that project was to investigate how augmented reality could be used to enrich the learning experience in museums without stealing the focus away from its attractions. During the research done in that project a prototype mobile application was developed, the same prototype will be used and developed further in this master thesis.

The aim of this thesis is to extend the prototype system with support for post-visit activities, and to evaluate it as a whole. The focus will be on how to use the data collected with the mobile application to promote reflective learning. I will create a more stable version of the prototype created during the fall semester, and also develop a website for supporting the post-game reflection session. Both mobile application and website will be part of an iterative development process that will be influenced by a theoretical study, usability testing, and an expert evaluation before the system is tested with its intended users in a realistic environment.

1.1 Problem definition

Looking at the numbers provided by Statistisk sentralbyra (SSB) it is clear that the interest in culture among the Norwegian population is decreasing. See figure 1.1

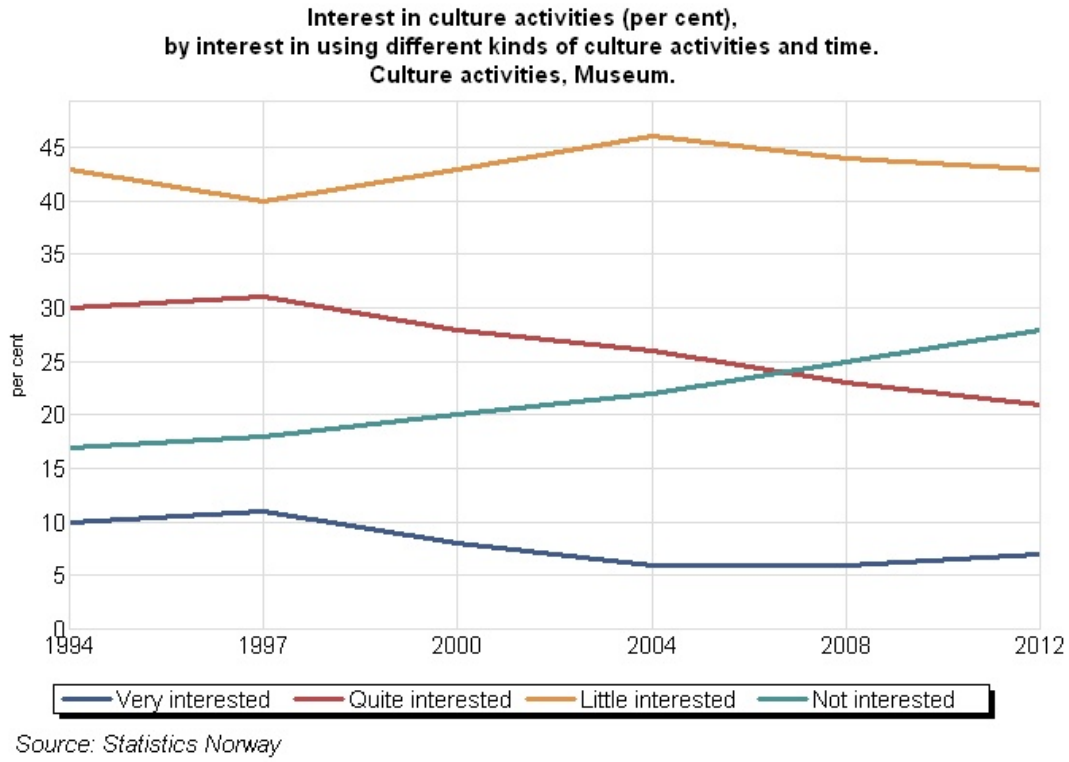


Figure 1.1: Showing interest in museums in the Norwegian population 1994-2012. Figure from SSB.no [1]

The decline of people with some interest (Very interested - Little interested) in museums compared to the increased percentage of people who is not interested at all shows the overall attitude towards the cultural activity. People are finding new ways to entertain themselves, and many do so online. Over 90% of the population use their smartphone or computer to access the internet daily[2]. Combining this new interest of technology with museums might help revitalize the interest and make people want to visit again.

Besides making museums more appealing to people, the mobile technology can prove to be beneficial in other areas as well. Collecting all the answers and monitoring an entire class can be a lot of work for an educator, and checking the answers can be very time consuming. Leaving these tasks to computers will lighten the workload of the educator, and enables him/her to give the learners more rapid feedback which studies has shown to have a significant and positive effect on students performance [3].

The approach to teaching kids about our cultural heritage has been the same for a

long while. By introducing some new elements to the otherwise outdated teaching method one might be able to create a certain level of engagement among the young learners. This thesis investigates how a serious mobile augmented reality game can engage learners and how the data generated from such a game can be utilized in a post-game reflection process.

Serious games are games created for a learning purpose. By merging the content of learning and the motivation produced in games they try create a more enjoyable experience. People are easier motivated doing something that they enjoy rather than doing something they "must", i.e. memorizing a list of facts. The game created to support the system described in this thesis encourages learners to seek out the information themselves in order to either create or answer questions. This way they have to read up on the material to obtain a good score.

Mobile augmented reality (MAR) utilizes the built-in components of a mobile device to add value to the physical world [4]. Typically using the devices camera to give the user an augmented view of an object or a place. MAR puts the information related to a painting in context and provides a new and engaging way to interact with it.

Reflective learning involves consciously thinking about and analyzing what one has done in order to improve ourselves. John Dewey's famous quote states that;

> *"We don't learn from experience. We learn from reflecting on experience."*

Boud et al. [5] presents three aspects deriving from Dewey's work where reflection is an activity in which people recapture their experience, think about it, and evaluate it. The potential of using technology to collect data from ordinary activities as visiting a museum, and using this data to support reflection has been shown to be growing [6]. The challenge will be to collect, organize, and present the data in way that enables the user to reflect on his/hers experience and learn from it. By using technology I hope to be able to capture parts of the users experience and use it to help them improve their performance by making the reflection process easier to overcome.

1.2 Previous Work

The work done in this thesis is a continuation of the report delivered in the course TDT4501 Computer Science, Specialization Project the fall of 2013. The goal of that project was to create a game that would enhance the experience and edu-

cational outcome of a museum visit without stealing the focus from the artefacts at hand. The outcome of this project was a mobile application that utilized augmented reality to enable the users to interact with information. The application was evaluated by a small group of PhD and master students at NTNU which uncovered some issues that would have to be fixed before conducting a more realistic evaluation.

Apart from the issues found during the evaluation, the application has some limitations. As of now the game is divided into two phases. During the first phase users scan paintings with their phone and add questions related to these, in the second phase they are asked to scan the images again to answer the questions created during phase one. Altering this process could make the system more flexible, and allow educators to tailor the game to suit their specific activity. Given the limited amount of time to complete this thesis I have decided to not drastically change the process of the game, but rather add functionality to support the reflection website developed during this semester.

In this thesis the focus is shifted from the on-site-game to the post-game reflection. Issues found during the evaluation of the application were sorted out, and a more stable version was used to conduct the evaluation done in this thesis.

1.3 Research questions

In this section I will describe the research questions defined for this thesis.

- RQ1: Does the use of state of the art MAR technology engage young learners?

  The first question aims to find out if the use of MAR is perceived as a fun and useful way to present information related to an image compared to traditional tutoring.

- RQ2: How can digital data collected during an activity be used in a collaborative post-game reflection session?

  The second research question aims at finding out what ways information collected from an activity can be used, and how it should be presented to the users during a reflection session.

- RQ3: How can a post-game reflection session help students improve their learning capabilities?

The last question looks at how the outcome of a reflection session can be used in order to help students improve their knowledge on how to become a better learner.

1.4 Research method

To try and answer the research questions defined above an iterative development process was used. This process led to the creating of a serious game for mobile devices and a website to support this game. The serious game was based on work done during the computer specialization project the previous semester. The first iteration was based on related theory and literature, with a functioning system as the outcome. The system was then developed further after conducting usability test and an expert evaluation before evaluating it with real users.

1.4.1 Development process

The first step of the development process in this project was to fix the known issues found in the mobile application, and then create the website to support the reflection session. The website was designed based on the findings in similar projects, and theory related to my work.

The third step consisted of a usability test to uncover any issues with the system. Users participating in the usability test was presented with the system, and asked to conduct different tasks in order to cover all aspects of the system. The findings in this step were used to further develop the system before having it evaluated by an expert and real school class.

Having the system evaluated by an expert, the fourth step in the development process, involved presenting the system to the expert, answer the questions she had, conducting an interview, and discussing different aspects of the system. The results of this evaluation were used to further develop the system and the guidelines on how it should be used.

After having applied the changes suggested from the expert evaluation, no further development of the system will take place. The results from step five in the development process, the user evaluation, were used to analyze the system in terms of the research questions.

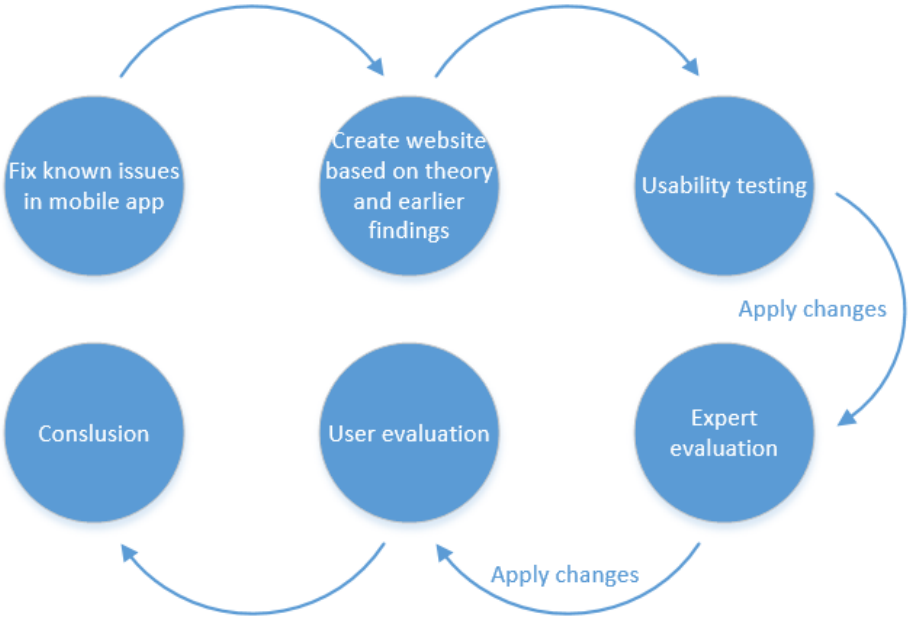


Figure 1.2: The process used to develop and evaluate the system.

1.5 Contribution

In this thesis a literature review on the reflective learning process has been done, a mobile application has been designed to collect data during a museum visit, and a website giving the users a graphical representation of the results was created to support reflection on the visit.

The main contributions of this work are:

- A mobile application available on multiple platforms that enables users to interact with information connected to paintings in a museum through image recognition and augmented reality. [1]
- A web application that enables users to reflect on the museum visit at a later point in time.

[1] A prototype of the mobile application was created during TDT4501 Computer Science, Specialization Project the fall of 2013, but further work has been done to ensure stability and sufficient/correct data collection.

- An expert and user evaluation conducted to explore the potential of mobile augmented reality (MAR) and post-game reflection in a learning environment.

1.6 Innovation

Blow I have listed the aspects of the system created for this thesis that I consider to be innovative.

- Combining user generated content, MAR, and image recognition to promote reflective learning.
- Using students phones to collect digital data during an academical field trip. Reviewing this data in a sorted and graphical way.

Similar approaches exist, but as far as I know, have not been applied in the same context.

1.7 Thesis structure

In this section I will describe the organization of the remaining chapters in this thesis.

Chapter 2 presents an earlier version of the system together with groundings for the changes I have made.

Chapter 3 describes the theoretical background for this thesis, including the high-level requirements defined for my system.

Chapter 4 presents an analysis of related systems based on the high-level requirements defined in Chapter 3, and how this analysis will influence my work.

Chapter 5 presents the functional and non-functional requirements defined for my system.

Chapter 6 presents the functionality and design for the mobile application and the reflection website based on the findings in previous chapters together with a scenario describing a full iteration of the system.

Chapter 7 presents the technology used to create the system, and why it was chosen.

Chapter 8 presents the usability study, how it was conducted, the results, and how it influenced my work.

Chapter 9 presents how the expert evaluation was conducted, the feedback I got form the evaluator, and how it effected my work.

Chapter 10 presents how the user evaluation was conducted, who participated, how it was set up, and the results of the evaluation.

Chapter 11 presents a discussion on the results and experiences from the usability testing, the expert evaluation, and the user evaluation in regard to the research questions defined in this thesis.

Chapter 12 presents the conclusion of this work and proposes ideas for future work.

Chapter 2

Earlier Prototype

The system developed for this thesis builds on the findings in an earlier version of the system called MagMAR[7] [8]. MagMAR was created to investigate how modern technologies could be used to create a better, more engaging museum experience for the young museum visitors. The work resulted in a system consisting of a website and an android application for supporting game sessions taking place in museums. The android application was based on a classical game called "Treasure Hunt". In the classical game players play using pen and paper. To start the game players are split into two teams and are given a list of questions that can be answered by finding the corresponding items and filling in the answers with a pen. To find answers to these questions players need to explore the museum by themselves. The team that answers most questions correct wins the game.

2.1 Intended use - MagMAR

The process of using the MagMAR system starts with the teacher setting up the session using a web interface. Here the teacher has to fill some information on each item to be included in the game session. For each item the teacher is required to fill in the title, a description, and generate a marker. The marker is placed near the museum item, and is used to identify it with the phone. When all preparations are done the teacher invited the players to the museum.

The players are split into two groups, and are given the equipment required to play the game. When both groups have the required equipment the game can start. Both groups have to enter the correct session ID to join the game. Now the teams can approach the first item. They find the marker that the teacher has

placed somewhere near the item, and uses their phone to scan it. After scanning it they will be able to read additional information about the item, and a button for submitting questions appear. Each question has to contain three answer alternatives in addition to the questions itself where one of them is marked as the correct answer. When the teams are done creating questions they need to press a button to confirm that they are done with stage one. During the whole game the teacher can see all the questions that are created in real time using web interface. The game allows for multiple creation of questions, but only the last one is saved for the other team to answer.

When starting stage two of the game, all items that were marked by the teacher should now have questions created for them. The teams switch places and starts searching for the items that has been marked by the teacher. Scanning the marker with their phone during this stage will reveal a button that allows the group to answer the question connected to an item. There are no limitations on how players can gather information, so using their phones to search the internet is allowed. When both teams has answered all questions, they are presented with the end game screen which shows them the final score.

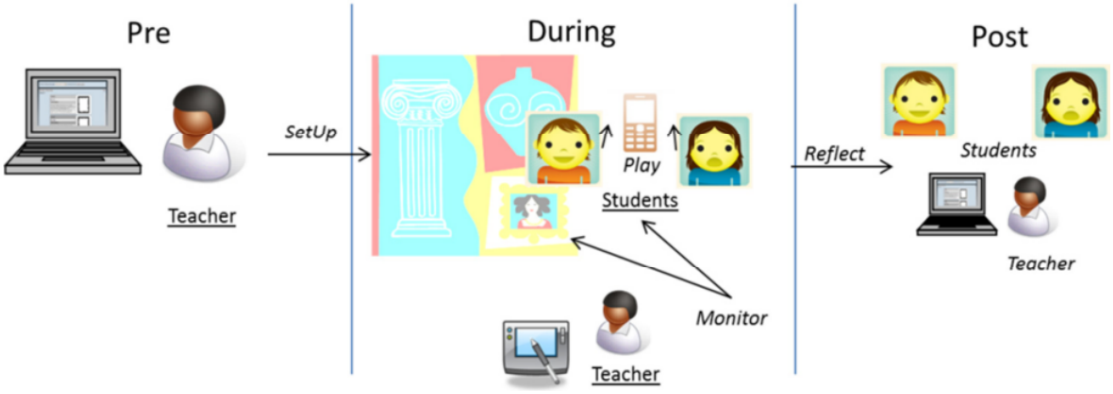


Figure 2.1: An overview of MagMAR intended usage. Source: [8]

Figure 2.1 shows the intended usage of the MagMAR system. The figure includes a post-game activity, but in the current version of the system this phase is not explicitly supported [8].

2.2 Differences from earlier system

As technology has progressed, and the purpose of the work in this thesis differs from the purpose of the work connected to MagMAR, some changes has been applied to optimize the system for my work. A summary of the changes can be seen in table 2.1.

musARum (the system described in this thesis) was developed from scratch, and now runs on all major platforms including iOS, Android, Blackberry, and Windows Phone 8. Instead of using QR codes to recognize paintings, the new system utilizes image recognition, thereby eliminating the need to physically alter the environment. The groups are now divided into small groups of 2-4 people instead of splitting the class in two, and the process of playing the game now allows all students to both create and answer questions for every painting.

The website that allowed the teacher to monitor the students in real time has been expanded with functionality to support a post-game reflection session. It now supports both individual and collaborative reflection by presenting the students with questions to trigger reflection, and data collected from the activity in an orderly way. To help the teacher guide his/her class through the reflection sessions, a set of guidelines is now provided together with the system. The new system also allows students to post questions anonymously between the activity and the collaborative reflection session.

Issue	MagMAR	musARum
Image identification	QR-code	Image recognition
Group size	Class split in half	Groups of 2-4 people
Supported platforms	Android	Android, iOS, Blackberry, WP8
Game process	Create questions for half of the paintings, answer questions for the other half	Create questions for all paintings, answer questions for all paintings
Post-game activities	None	Individual and collaborative reflection session

Table 2.1: Differences between MagMAR and musARum

2.2.1 Intended use - musARum

Figure 2.2 shows how musARum is intended to be used as compared to figure 2.1 which shows the intended use of MagMAR. The changes mostly includes alterations in the gameplay, and functionality to support the individual and collaborative reflection sessions.

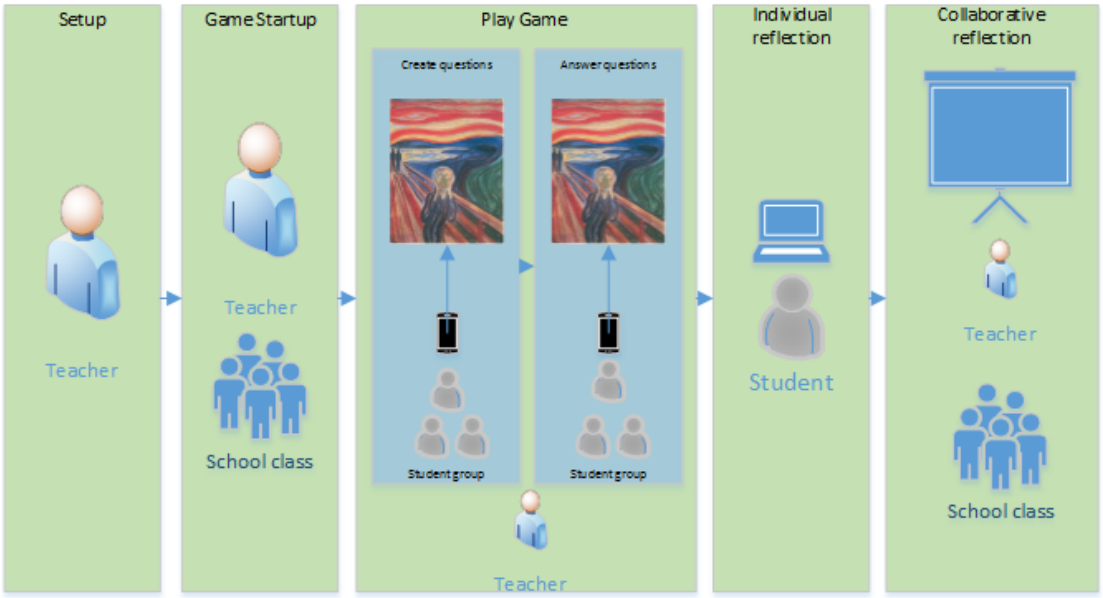


Figure 2.2: An overview of musARum intended usage.

The first step of using the system is the *Setup*. When a teacher has decided to use the system, s/he will need to specify the objects they want to focus on while playing the game, and provide related information. During the *Game Startup* the teacher explains to the students how the game is played, provide them with the information they need to start playing, and divide the students into groups. *Play Game* is where the students actually play the game. First the groups are told to find specific paintings and create questions related to these. When all the paintings specified by the teacher during the setup has been covered, the students proceeds with answering the questions created by the other groups on each painting. After all the groups have answered at least one question connected to each painting the game is over. Before sending the students home the teacher has to announce the homework and explain to them how it should be done. When students get home after the visit the *Individual reflection* can take place. Here they have to answer questions related to the material in the quiz and the visit itself to make them reflect on their experience. While doing this, the students are also encouraged

to post questions that will be answered by the teacher during the collaborative reflection session. The *Collaborative reflection* session will typically take place in a classroom the following day. Here students will get the answer to the questions they posted during the individual reflection, and have the opportunity to discuss and reflect on their visit. This session will be guided by a website presenting all the data collected from the students while they were playing the game.

2.3 Grounding choices

This section presents a brief grounding of the changes made in comparison to the MagMAR system. It is based on the issues pointed out in the report that addresses MagMAR written by Igoris Trimailovas [7] and the findings in the computer specialization project of the fall 2013.

2.3.1 Image recognition

QR codes has the disadvantage of requiring the user to focus his/her attention on the sticker containing the code, and makes it more challenging to place augmented objects around the painting itself. By using image recognition to select and load augmented content the painting will always be in focus and users can look at it while also viewing the provided information. It eliminates the need for placing any physical objects such as the code sticker. In addition image recognition allows scanning from a larger distance, and makes it easier to enable large amount of augmented objects [9].

2.3.2 Group Size

Instead of dividing the class into two groups, it was decided to design the system for multiple groups consisting of 2-4 persons per group. The backside of splitting the class into two big groups is that some students may end up not participating and letting others do the work, also it is hard for a big group of people to interact with the content on the smartphone at the same time. Having each student play individually would leave the players to rely on their own possession and acquisition of knowledge. This would require one device per participant, and the need for technical and educational assistance may be more than one educator can handle on his own. The collaborative aspect of the game would severely diminish, and the whole team spirit feeling of the session would go away. Using the system with

groups consisting of 2-4 students should create a competitive environment where each partaker is more inclined to take active part in the activities, and thus benefit more from the game session.

2.3.3 The Process

When using the MagMAR system, users created questions for half the paintings and then switched places with the competing group to answer the questions they had created. In musARum all groups create and answer questions for all the paintings by following a route defined by the teacher when setting up the session. The route is repeated after finishing the first phase, this allows users to look around the museum during the first phase so that they have a better knowledge of where the different objects are located for when they have to find them later. Also, playing the game using the same process as in MagMAR would not be possible with more than two groups.

2.3.4 Portability

Portability was one of the issues that were pointed out with the MagMAR system. Experimentation showed that users were not happy with the device they were provided with, and that most of them would rather use an iPhone or a tablet PC. Therefore musARum was created as a cross-platform system that allows users to use whatever device (almost) they like to play the game.

2.3.5 Web Interface

The web interface still supports real-time monitoring, but now provides functionality to support the reflection sessions as well. Feedback on the earlier system also suggested that the site needed to be designed so that it suited the needs of the end users better, and that it was hard to use without external help. Therefore the website created in this thesis has focused on keeping the design as simple and user-friendly as possible while at the same time offering the functionality desired by the teacher. Guidelines on how to use the site will also be provided to the teacher.

Chapter 3

Problem Elaboration

During the fall of 2013 we looked into the use of augmented reality combined with image recognition in a mobile application. This combination of these technologies worked well, and enabled us to create the prototype we had in mind. It also eliminated the need for physical alteration at the location of interest.

In small groups the users are asked to find a painting and scan it using their phone. When the correct painting is scanned they can see the information related to the painting displayed through augmented reality. After reviewing (optional) this information they must create at least one question before they can continue to the next painting. After scanning the last one they can start the second phase of the game. In the second phase they will be asked to scan the same painting, only this time they will have to answer the questions created by others. When a group has answered at least one question connected to each painting the game is finished.

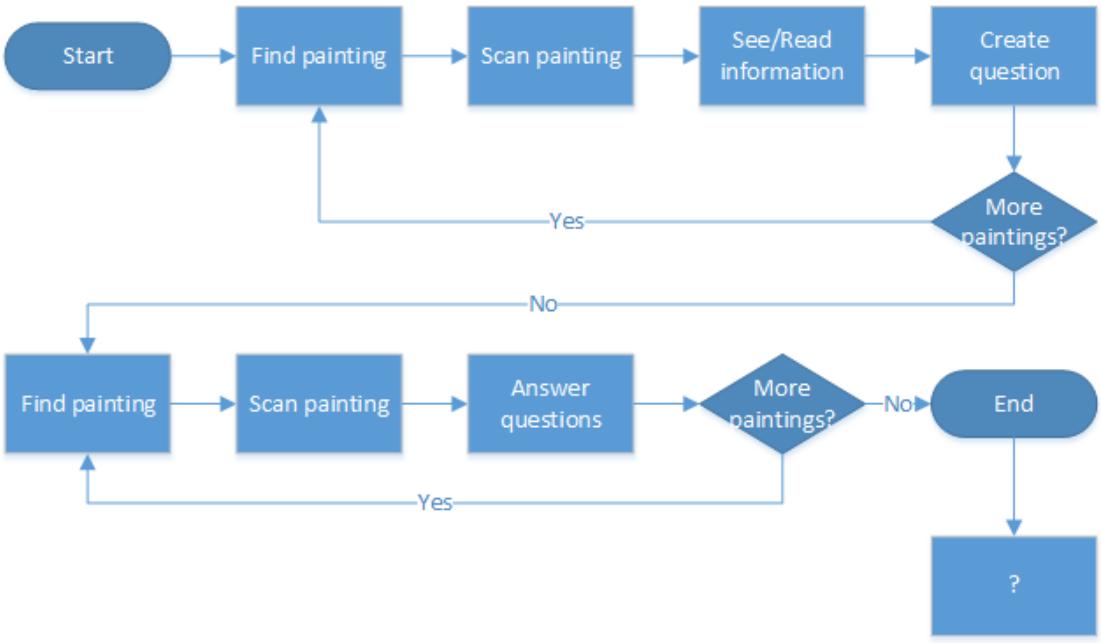


Figure 3.1: Game flow of the application created fall 2013

In a serious game like this it was important to balance fun and learning. After conducting a literature review we designed the game so that by using their creativity and cooperating as a team the group promote their own enjoyment, and at the same time making it more challenging for the other groups. By coming up with questions that are hard to answer a group can make it harder for the competitors to score points when answering their question.

The flowchart in figure 3.1 shows how the game progress during a museum visit, but not what will happen when the visit is over. The system collects data while the learners are playing, but how can this data be used in a post-game reflection session? The main learning objective of a visit like this is to increase the students' knowledge about art and the history surrounding it. But with the available information it also gives students and educators opportunity to reflect upon, and develop their cooperation skills.

Collected data can also be used to reflect on how questions should be formulated, how to connect the different paintings, and give the educator feedback on what parts of the curriculum is hard to learn for the students. Improving the students own ability to learn, and help the educator teach his/hers students.

3.1 Cultural Heritage

Our cultural heritage consists of tangible culture (i.e. monuments, buildings, art, and books) and intangible culture (i.e. knowledge, traditions, and language). Art history defines society and culture of civilizations, and is a big part of the world's cultural heritage. Teaching young generations about this heritage is important to make sure it is not lost and forgotten [10]. Most of today's young learners do not find the typical visit to an art museum very exciting, and this needs to change if the knowledge is to be preserved.

3.2 Serious Games

A serious game is a game created for a primary purpose other than pure entertainment. These games are being used more frequently to educate people, and are beginning to play a vital role primary schools, high schools, collages, and universities. They are being used to educate students in a more efficient and better way[11]. In this section I will look at the properties of serious games aimed at educating young learners.

3.2.1 Maximizing Learning Output

Balancing Three Design Foci

When creating a serious educational game there are three different design goals that have to be considered in parallel while creating the game. These are: creating an engaging game, making sure the content of the game is relevant to the training objective, and designing the game to work in the intended context of use[12].

Cognitive learning outcomes

Cognitive learning outcomes include three subcategories of declarative knowledge, procedural knowledge, and strategic knowledge . The three subcategories is defined bellow as found in Garris et. al. work [13].

Declarative knowledge enables a student to describe a rule, and possibly apply it in practice. This kind of knowledge is typically taught through classroom tutoring, but studies has shown that students who learn through games are able to answer related questions more accurate than those who does not [14].

Procedural knowledge refers to knowledge on how to perform a task. Whitehall and McDonald found that students who used a variable payoff electronics game during training achieved higher scores on electronics troubleshooting than the students who received the standard drill and practice [15].

Strategic knowledge Strategic knowledge requires applying learned principles to different contexts or deriving new principles for general or novel situations. This implies the development and application of cognitive strategies and understanding when and why principles apply. For example, Wood and Stewart found that the use of a computer game to improve practical reasoning skills of students led to improvements in critical thinking [16].

Post-Game Reflection

Reflection is widely considered a vital part of the learning process. Much of the effort put into teaching and studying is wasted if students do not adequately process their experiences; they need time dedicated to reflecting upon them[17]. Besides encouraging learners to reflect on their actions, it also provides a goal to strive after. The post-game reflection presented in this thesis will present the scores obtained by the participating groups and reveal who "won" the game. While winning the game will be the goal students strive after, this is only an element implemented to help the students reach goals the system tries to achieve.

3.3 Competitive games

Individuals desire an optimal level of challenge, meaning that we are challenged by activities that are not too easy nor too hard to conduct [18]. When presenting such a challenge in a serious game the goal of the game should be clearly specified, but the possibility to reach this goal should be uncertain. Goals must be meaningful to the individual to make them stride to reach it. Competitive motivations can serve to make these goals meaningful [19]. The competitive aspect of the game described in this thesis will be present during the whole game, but the results will not be presented to the learners before the end of the post-game reflection session. This is to make sure the students will perform their best in hope of winning throughout the whole game, and also pay attention during the reflection session. Making the scores available as they are playing could have a demotivating effect on the groups falling behind, and make them less enthusiastic about playing. Adding game features like this has been experimented with and findings showed that students improved their

performance and training outcome compared students playing a game were such game features was excluded [19].

3.4 User Generated Content

A big part of the system created for this thesis depends of content that is submitted by the users. Without the submissions by users there would be no quiz for the students to partake in. By designing the system so that the students create a big part of the content themselves, the teacher does not have to spend as much time setting up the activity as s/he would otherwise. The content supplied by the users in this system consists of; the questions and the response alternatives, the question ratings, and the questions added between the museum visit and the reflection session (these questions being anonymous).

There are of course downsides to letting users create the content, the most obvious one being that the teacher has no control of the quality/relevance of the questions that are added. This can be fixed by letting the teacher approve questions before they are added, but in this case that would be too time consuming. Since questions can be traced back to the groups, and will be discussed during the reflection session, the students will think twice before submitting something irrelevant. This kind of protection is based on the same thought as YouTube had when they encouraged their users to post videos/comments using their full name [20].

3.5 Reflection

We learn from experiences that allows us to absorb information (read, hear, feel), do something (an activity), and interact with others (socialize)[21]. We also learn by reflecting on such experiences[22]. Reflective learning is the process of examining and exploring past experiences, not setting aside time to do so can result in a not-optimal learning outcome and wasted time for both educators and learners. As mentioned in section 1.1 Boud et al. divide reflection into experience(s), reflective process, and outcomes. Figure 3.2 illustrates the connection between the three stages.

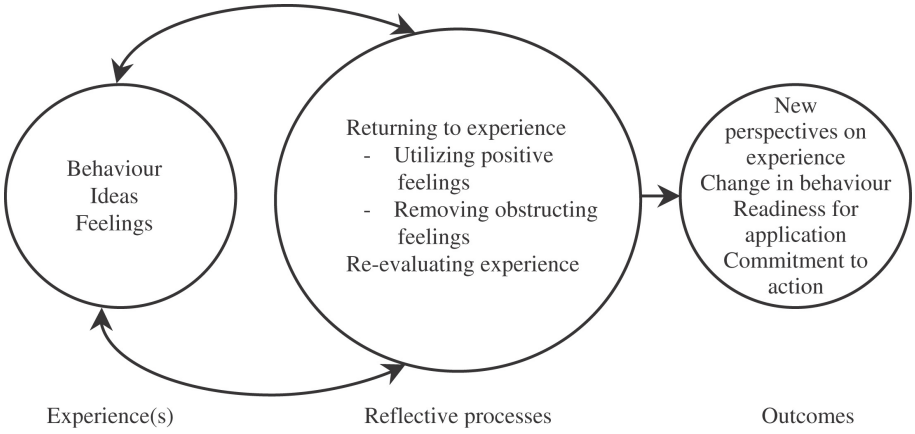


Figure 3.2: Boud's reflective process model. Source: [5]

In Boud's model the experience has to take place before the reflective process can start, this is because the reflective process is based on the experiences of the learner. The learner is later able to return to his/her experience and re-evaluate it. A successful reflective process will produce an outcome which results in a new perspective on the experience, behavioural change in the learner, or a state of preparedness to apply new skills.

As mentioned earlier, a lot of research point out how important reflection is for the learning process. Here I will elaborate by looking at systems that promote reflection to find out what makes them useful, look into the benefits of rapid feedback, compare the properties of individual and collaborative reflection, and present a model supporting computer supported reflection.

3.5.1 Individual and Collaborative Reflection

Individual reflection lets a person withdraw back to a place where they can think in private without being influenced by other individuals. In a research paper written by Ogawa et al. [23] it is stated that "Reflection by oneself is the preparation stage so that students speak own opinion at the group reflection". This indicates that when individual reflection is followed by a collaborative reflection session students use it as a preparation before conversing with others. This can improve the contributions during the collaborative reflection session, and supply the participants with a wider range of viewpoints than if the individual reflection had not taken place.

3.5.2 Rapid Feedback

Research has shown that students find rapid feedback of their state of learning helpful and that is also helps to improve their test results [24]. In this system the feedback will be provided by the web-interface designed for the reflection session. When students are given rapid feedback, the threat of disappointment increases, and the desire to avoid this disappointment works as a potent motivator to perform well[25]. The feedback should be descriptive and focused on the task, and should not be judgemental. It is important to have time to discuss the feedback and make sure everyone is prepared for the discussion [26].

It is important to distinguish between receiving feedback and reflecting on an activity. The system and the teacher can provide the students with feedback, but the students themselves, together with the teacher, has to reflect on their experience. The feedback is provided so that they have material to reflect upon. Reflection leads to growth of the individual, whereas feedback tends to promote technical proficiency[27].

Typically teachers spend a lot of time grading papers, which leaves less time to give the students feedback. Using a system like the one described in this thesis could shorten the time spent on grading tests, and instead give him/her time to give students informative feedback on what they did.

3.5.3 Related Systems

No system that supports reflection after a museum visit was found, but a quiz game in the classroom context called Kahoot! used some of the same methods to motive participants as the system described in this thesis.

Kahoot! is a game-based classroom response system [28] which works as a motivation for students, and helps the educator map the knowledge of his/hers students. The game session is created by the teacher who fills in the questions and the response options. After the teacher has created the quiz, it is launched on a projector (or something similar) in front of the class to get their attention. Students log in to the system using their own devices, and also answer the questions appearing on the shared screen through their device. The students goal for this game is to reach the top of the on-screen leaderboard.

Reflection is used in many different contexts, not just in education. The last few years wearable computers have become more available to the public, and people are using it in a great variety of ways. Fitness might be the most popular one as of today, and the different devices that are being used works in the same way as

the application described in this thesis. Data is collected during an event, and the user can go back at a later time and review this data. Here is a brief description of some of these fitness systems:

FitBit Flex is a wristband contraption that tracks your steps, distance, and calories burned throughout the day. It also gives the wearer feedback on how the user is doing compared to his/hers personal goals. It synchronizes the collected data to a computer or phone, and lets the user review it from there.

Gear Fit is a smartwatch and fitness tracker that works together with the users mobile device to give him/her feedback on their activities, and also giving them the opportunity to go back and review these activities.

3.5.4 The MIRROR Model

The MIRROR computer supported reflective learning (CSRL) model presents a way to describe cases of reflective learning at work. In contrast to other models of reflective learning it can describe both individual and collaborative learning and learning that impacts larger parts of an organization. The MIRROR CSRL model presented in figure 3.3 shows the four stages of the reflection present in the CSRL reflection cycle. The model depends on a reflection session taking place; it can be both individual and collaborative sessions. It also shows how an experience and a reflection session connects to produce an outcome that can be applied and lead to change.

The model was chosen to describe the musARum system because of its ability to describe both individual and collaborative reflection sessions, and its cyclic way of describing work and reflection. The model makes it clear what the outcome of the reflection session is, this leaves the students with something concrete that they can change before partaking in similar activities later in time. Instead of improved routines which could be an outcome at a regular workplace, the outcome in this context will be improved knowledge on how to learn and perform better, and change in the individual's knowledge on a subject.

The first three stages of the model in figure 3.3, plan and do work, initiate reflection, and conduct reflection session are the ones this thesis in mainly build around. The developed system supports these stages by collecting data during work, and making it available to for the reflection session. The system also allows users to reflect individually as a preparation for the collaborative reflection session. A brief description of the four stages in the CSRL reflection cycle is given in the following sections.

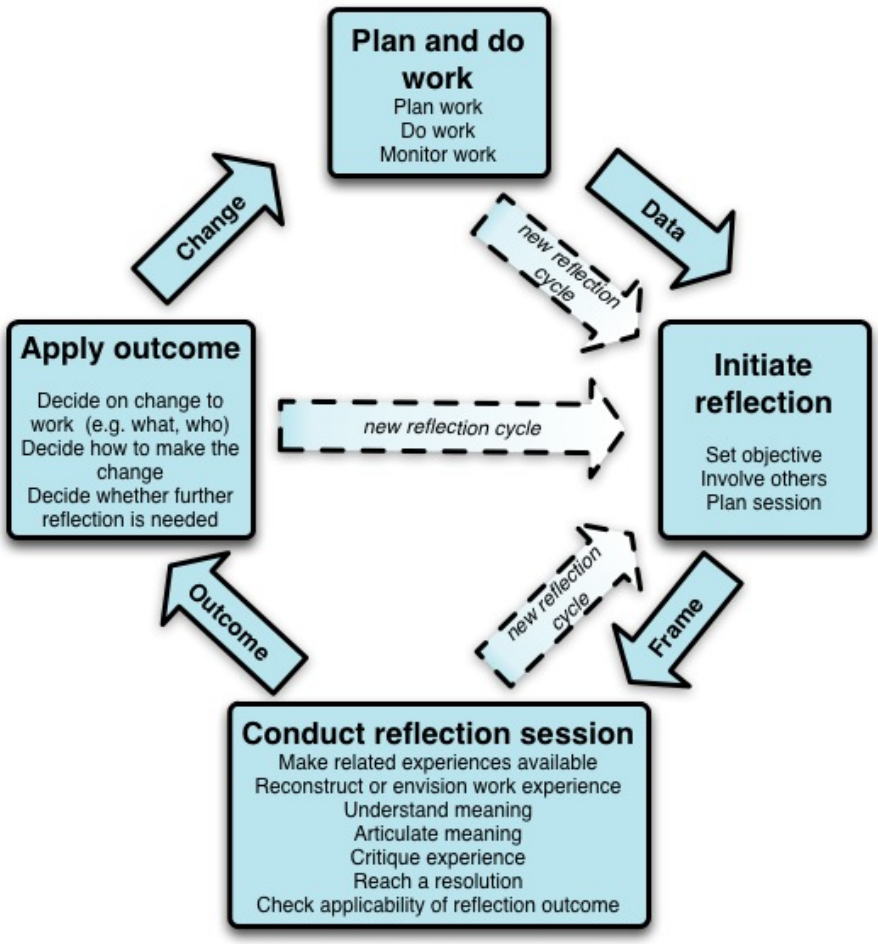


Figure 3.3: The MIRROR CSRL Model

Plan and do work

The first stage refers to conducting an activity. This involves the particular kind of work that involves planning other work, conducting work tasks, and to observe the state of work. It also includes simulated work in real or virtual environments.

Initiate reflection

This is where the reflection cycle starts when reflection has been triggered. The initiation of reflection may include setting an objective, involving others, and plan-

ning the session by determining the time, place, and approach. It produces a more or less explicit frame. In the system described in this thesis the reflection initiation will be conducted by the teacher setting the time and place. The approach is mostly defined by the system, but can partially be defined by the teacher.

Conduct reflection session

This stage is based on the frame resulting from the reflection initiation. The session has an objective, a reflection topic, has a certain duration, involves one or more participants, and should result in an outcome. In the reflection system created for this thesis the material that was available during the activity to be reflected upon will be presented together with the material that was produced during the same activity, and students can share and discuss their experiences. The outcome of this session will include increased knowledge on the subjected reflected upon as well as ways to improve future activities.

Apply outcome

The last stage is where reflection outcomes are used to create change or to supplement further reflection. This includes what will be changed, who will be involved, and how to make the change.

This model will be used while developing the system and to decide how the process while using the system will be. Defining guidelines regarding the process intended for the system will help teachers achieve the desired goals while using this system.

3.6 Usability

Today's youth has grown up with technology, and most of them are therefore comfortable using it in their everyday life. Familiarizing themselves with new applications, websites, mobile devices, etc. usually doesn't take a long time. Even though they might be "fearless" about technology, young people (as well as others) usually have a specific goal in mind when visiting a website. Making it easy for students and educators to understand how they can achieve this goal and accomplish their task through the website is important if you want them to spend time using it. Research has found three factors that impact how well young people are able to navigate a site [29], these are:

1. Insufficient reading skills
2. Less sophisticated research strategies
3. Dramatically lower levels of patience

Since the students in this case will be provided with the location of the website, it is mainly point 1 and 2 that must be considered while developing the reflection system described in this thesis.

3.7 High-level Requirements

The previous sections of this chapter describe theory on serious games, reflection systems, and user-generated-content. From this theory I have picked the most important elements to consider while creating a reflection system for young learners.

3.7.1 Feedback

The system should provide the students with answers to the various questions, and also give a comparison to how they scored compared to the other groups. This information should be available as soon as the activity is over, and the students have the visit fresh in mind. Making students aware that they will receive feedback shortly after playing the game will motivate them and make them perform their best while playing.

3.7.2 Engagement

The reflection session should engage the students, just as the game should. The players do not get to know their score while playing the game, so the system should include functionality to display the score, and use this to engage the users. It is important, though, to keep the users attention through the whole session and therefore not reveal the group scores too early.

3.7.3 Privacy

Some users find it hard or embarrassing to speak in front of a crowd or are afraid that their questions might be considered stupid by others, therefore questions

added anonymously should not be possible to track back to the user that posted it.

3.7.4 Usability

The system should be as simple as possible to enable people with average technical skills to use it. It should also be right to the point so that users does not become impatient and lose their focus. The terms and language used in the system should be easy to understand, and should not require the user to be an advanced reader. It is important that everyone wanting to use the system should be able to.

3.7.5 Learning

The system should provide or encourage its users to search out information that can expand their knowledge on a subject. Also, it should enable them to see how they can improve their performance for future activities.

Chapter 4

Related work

This chapter contains an analysis of learning games that supports reflection or has the properties needed to support it. I look at one game created to support children visiting an archaeological site, and three systems supporting reflection in the workplace. The high-level requirements identified in the Problem Elaboration will be used to analyze the systems in relation to the work in this thesis.

4.1 Selection of games

When doing research on the related work only one game in the museum context that supported reflection was found. When searching for system that could support reflection on a museum visit, I found that there are a lot of apps out there designed to give users information about paintings in specific museums, but very few focusing on how to make the users reflect on their experience. Most of the applications were also designed for specific museums, and could not be used anywhere else. This lead me to search out systems that were designed with focus on making the user reflect, instead of only looking at systems designed for museums. The context in which these systems are applied may be different, but the properties they have to support reflection can be used in other areas as well. The other applications found where mostly created to support reflection in the workspace, so before selecting which ones to analyze I had to find the systems that were the most similar to the one created in this thesis.

Explore! was selected because it was the only game supporting reflection in a museum(archaeological park) that I was able find. It gathers data during an activity, and visualizes it in front of the learners during a reflection session. The other

applications are results of a research project called "Mirror - Reflective learning at work" [30]. The vision of this project is to empower employees to learn by reflecting on their work and personal learning experiences. KnowSelf was the first application that caught my attention. It was chosen because it collects, analyses, and visualizes data, much like the system created in this thesis. ClinIC is a game that takes place in a 3D virtual environment, it pushes players to explore situations in order to increase their knowledge, and triggers reflection by presenting the users with questions that create dilemmas. Medical Quiz was selected because it combines a quiz and reflection to improve the learning process.

4.2 Explore!

Explore! [31] is a system aimed at supporting children exploring sites of cultural interest. The game consists of three phases: introduction, game, and debriefing. First, the introduction starts, the teacher illustrates the rules, divide the students into groups, and give them the necessary equipment. Next up is the game phase. Each group has to solve a set of missions which are communicated to them through text messages. When the missions (typically identifying a target place) are completed the students get a 3D reconstruction of the place as a reward. When the students have completed their missions they meet up with the teacher in an indoor space for debriefing. Here students reflect upon their experience with the help of an application running on a computer. The application projects on a large screen the map of the site. See figure 4.1. Guided by the teacher, students have to indicate how to position the target places on the map. The application also displays a 3D reconstruction of the site.

4.2.1 Feedback

During the debriefing phase, students are shown the path followed by each group during the game. And based on the analysis of errors and performance time, the winning team is announced. Other than this, feedback is given through discussions or directly from the teacher.

4.2.2 Engagement

The field study done with this system demonstrated that players were very involved in the game. They played with attention and motivation, and were careful not to

Figure 4.1: A screenshot from the debriefing application used in Explore!

commit errors. The participants reported that they *"tried hard to win"*, and that they *"did not want their team to lose"* [31], which suggests that the team spirit was a big motivation for the players. The desire to be announced "the winner" is also a factor that drives engagement.

4.2.3 Learning

The learning outcome of the system was assessed through two tests. One conducted prior to the debriefing, and one conducted after. The players answered 10 questions in each tests. In the one prior to the debriefing the players answered, on average, 6.9 items correctly. And the test conducted after the debriefing had an average score of 8.3 correct answers, proving that the debriefing phase is a fundamental step in the learning process.

4.2.4 Summary

The most interesting and relevant points in relation to the research questions defined in this thesis are listed below.

- Announcing a winner during a post-game activity.
- Pushing players to perform for their team.
- Enabling players to reflect on their performance during a post-game activity.
- Engaging students with state-of-the-art technology.

4.3 Application from the MIRROR project

MIRROR is a 4 year research project that is founded by the EU under **IST FP7**. Bellow is a description of the project objectives as written on their website[1].

> The overall objective of MIRROR is to empower and engage employees to reflect on past work performances and personal learning experiences in order to learn in "real-time" and to creatively solve pressing problems immediately. MIRROR shall help employees to increase their level and breadth of experience significantly within short time by capturing experiences of others. A prerequisite for exploring innovative solutions in this context is to rely on human ability to efficiently and effectively learn directly from tacit knowledge - without the need for making it explicit.

This project has produced a variation of applications supporting reflection. Below is an analysis of the ones most relevant to this thesis.

4.3.1 KnowSelf

KnowSelf [32] is an application created to support reflective learning connected to time management and self-organization. The application logs what activities the user spends his/her time on while on the computer, and provides an analysis of how they spend their time at work. Since the application is only able to gather information from activities on a computer, it targets users who spend their workday in front of a screen.

[1] http://www.mirror-project.eu/aboutus/about-mirror

The users interact with the system through a web application. An example can be seen in figure 4.2 found on the MIRROR-project website[2]. Here users can navigate through the application, seeing how much time they have spent on the different activities. The timeframe can be changed through the timeline at the top, and additional information about single activities can viewed by selecting them from the menu at the left side of the window. KnowSelf also allows the user to enter "incognito mode". This means that when a person use their computer for activities they do not want recorded they can stop the automatic recording of applications and resources by pushing a button. After inspecting the data visualized in the application, users can write down and store their thoughts and observations as reflection notes.

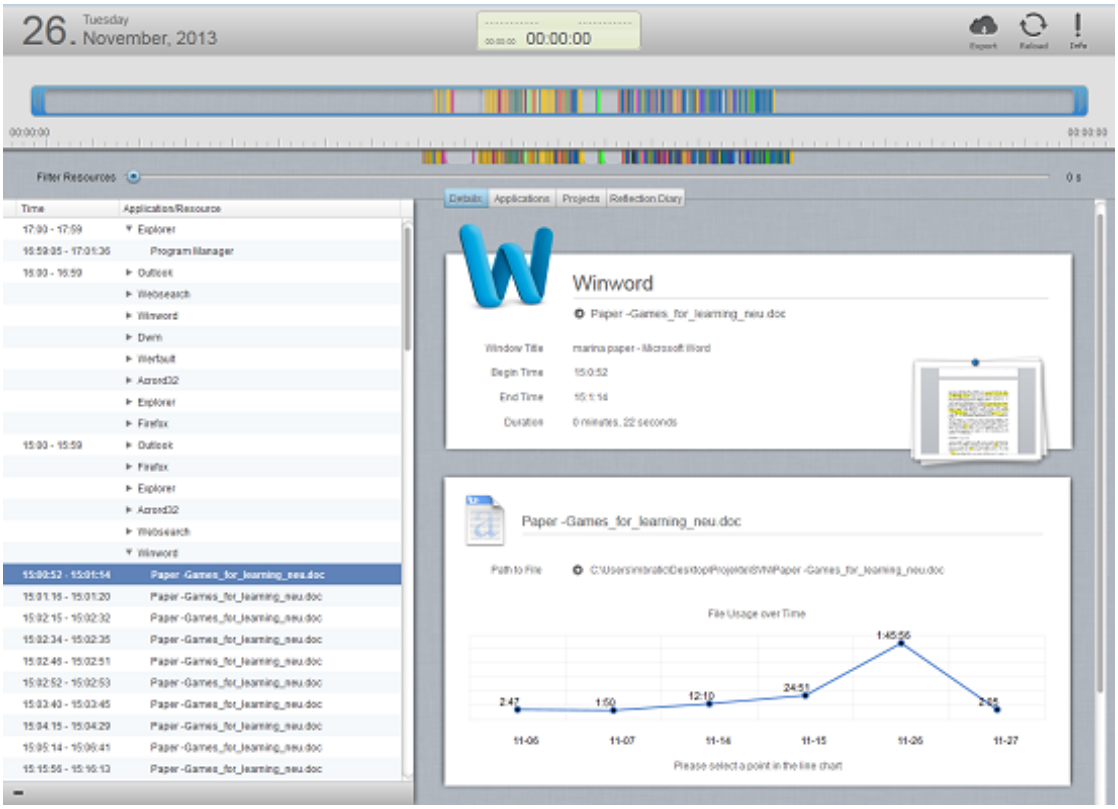


Figure 4.2: A screenshot of the web application user interacts with in KnowSelf

[2]http://www.mirror-project.eu/showroom-a-publications/mirror-apps-status/93-taskdetection

Feedback

KnowSelf presents the user with information about how they spend their work time using visual graphics. The information consists of how much time the user has spent on various activities on his/hers computer, and can be viewed on a daily, weekly, or monthly basis. Users can also see what file has been edited during the activity, and a screenshot of the application to help them remember what they were doing.

Learning

The main goal for this application is to support reflective learning regarding time management. It uses the collected data to trigger reflection and make the user evaluate his/hers time use. Upon testing the application, the overall theme by those who participated in the test was a surprise about their actual time use. Several of the participants also reported that they were able to identify ineffective time management habits, and some of these took measures to change their time management behavior[33].

Usability

Presenting users with large amounts of data without them knowing what to do with it can easily scare users away. By visualizing this data in graphs and pie charts it becomes easier for the user to understand, and makes the experience of reviewing the data more pleasant[34]. Other than presenting data, the graphical user interface enables the user to adjust the timespan in which s/he wants information from. This is done by adjusting a blue frame that encapsulates the activities for the wanted timeframe. Most of the participants that tested the application thought it helped them getting an insight in regard to time, but it did not help them improve their time management practices [33]. The test results also points out that there is a need to focus on explaining what the meaning of the recorded data is, and help the users to change their behavior accordingly.

Privacy

To prevent users from feeling their privacy is being invaded the application allows them to decide for themselves whether or not it should record data. If a user is on his computer browsing Facebook or reading news he/she would not want those

activities to be logged, and can therefore disable the collecting of data temporary.

Summary

The KnowSelf application was developed to support individual reflection in the workplace, but some of its features could be relevant in the context of a classroom as well. These features are:

- Collection of data in background.
- Visualization of data.
- Incognito mode - Disable data logging to ensure the privacy of users.
- Collected information is instantly available to the user.
- Storing reflection notes.

4.3.2 CLinIC - The Virtual Tutor

CLinIC [35] is a serious game focusing on the communication between nurses and patients. It aims at making users reflect around difficult dialogues and to maximize the learners ability to self-regulate their training with the support of a virtual tutor inside the game. It pushes the user to explore situations in order to gain knowledge of what to do, and why they should do it. Reflection is triggered by posing questions that create dilemmas.

Upon starting the game, the users are presented with information that will guide them through their game experience. Users also have the possibility to play a tutorial in order to get to know the game. After this introduction user can start the real game which is situated in a 3D hospital. Here users are asked to perform various tasks in order to take care of their patients. The gameplay consists of different branching stories presenting users with a set of options on what actions to take in order to help their patients. At the end of each branching story user will have the possibility to train some competences in the health domain through different mini games. Each action taken during the game will affect the overall score. Throughout the game users can ask "Maria"(the virtual tutor) for help by pushing a button. Maria will sometimes appear in a pop-up window in difficult situations even if the user has not pushed the button. After completing all tasks users can join the tutor in an in-game staff room to receive feedback on how they did during the game. At this point the users will be able to read all data that

has been collected during the gameplay in a learning diary and reflect on their experience.

Feedback

Feedback in CLinIC is received through the virtual tutor "Maria". While still inside the game, Maria gives the player feedback about their performance with respect to time management and patient satisfaction. Other than this, all the notes collected during gameplay is available for the user to review.

Engagement

ClinIC provides a realistic looking 3D virtual environment to engage its users by making the experience as realistic as possible.

Learning

To teach the users about competences that are important in the health domain, the game offers mini games after completing a branching story. An example is the ability to communicate in a more emphatic way with patients. Other than this, users learn through the feedback given by the virtual tutor near the end of the game and by reflecting on their own experience.

Usability

As soon as the user enters the game, an info box is displayed. This box contains information on how to navigate inside the virtual environment, and explains the different elements of the user interface. After viewing this information users can play a tutorial to figure out how stuff works before playing the actual game. Throughout the game user will also get hints and tips from the virtual tutor to help them perform better.

Summary

CLinIC takes place in a 3D virtual environment, but transferring some of its features into the real world and applying them in another context should not be a problem. Here are the most interesting features found in this game:

- Mini games used to promote learning.
- Allowing user to play a tutorial before starting the game.
- Allowing users to read all the notes that has been collected during gameplay.
- Giving users automated feedback based on different parameters.
- Offering in-game hint through the virtual tutor.

4.3.3 Medical Quiz

Medical Quiz [36] in an application designed to support nurses working at a stroke unit reflect on their work. The application consists of two types of quizzes, one where there is a time limit, and one where there are twenty randomized questions. I both cases the goal is to trigger individual reflection or to motivate players to evaluate their experiences during work.

After starting the game and logging in with personal credentials, users can decide which quiz type they want to play. Choosing the timed version of the quiz gives them three minutes to answers as many questions as they can. When the time has run out, the player will automatically see his/her results. Choosing the other option, Twenty Question Quiz, will give the user twenty randomized questions. Some of these questions will have reflection questions added to them automatically. These reflective questions are added to initiate the reflection process. After answering all the questions in the quiz the user will see which ones s/he got right and wrong. A screenshot of the application found on the MIRROR website can be seen in Figure 4.3.

Feedback

Immediately after finishing the quiz, the user can see what answers s/he got right and what questions was partially right. In addition all previous scores are stored so that the user can see their learning progress.

Learning

The goal of the quiz is to trigger individual reflection and through this make the users learn from their own experiences. To facilitate this reflection several reflection questions have been integrated into the quiz. These questions are intended to serve

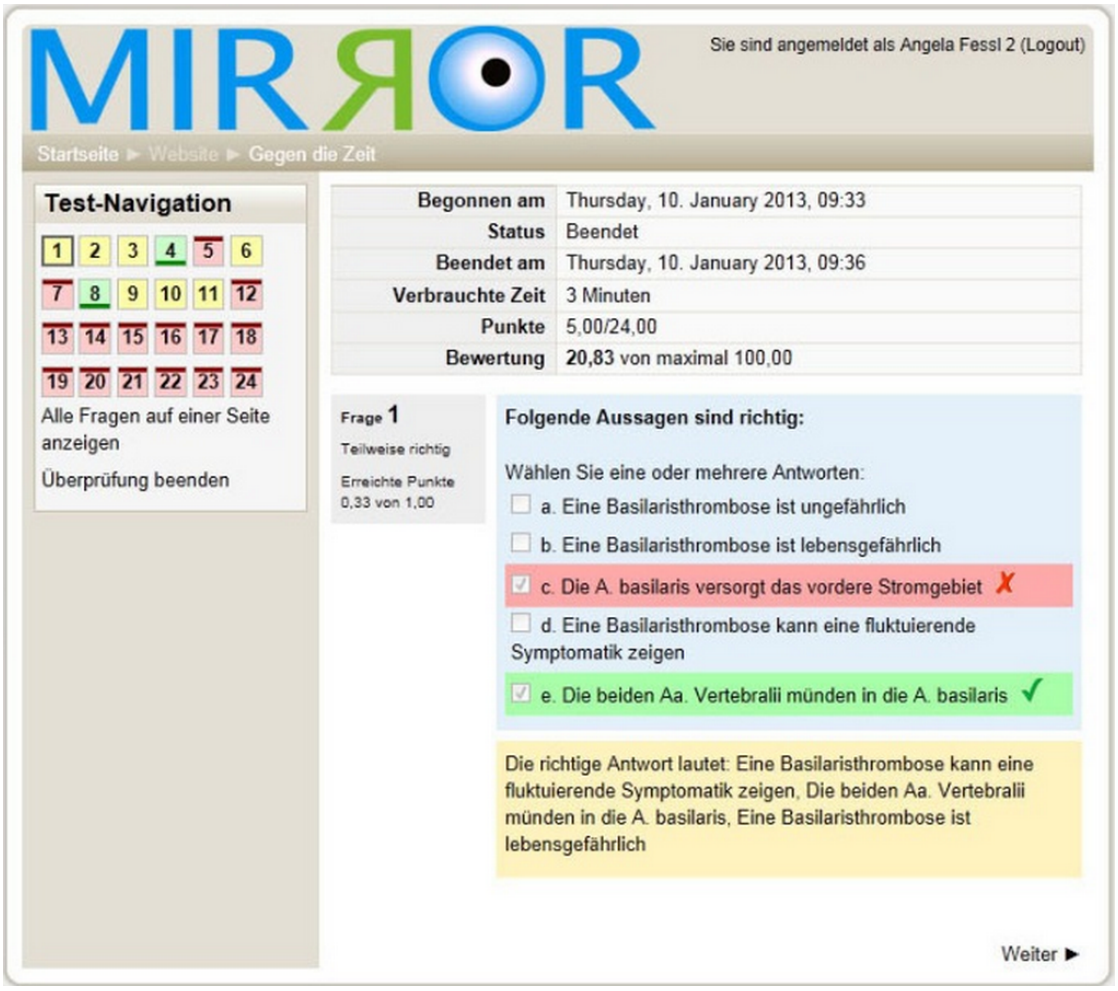


Figure 4.3: A screenshot of the timed quiz

as reflection amplifiers and to provide guidance throughout the reflective learning process.

Summary

The Medical Quiz application utilizes a quiz to serve as a trigger to initiate reflection, and make the players think back on their experience. Like the system described in this thesis, nurses partake in an activity, and are encouraged to reflect upon it at a later point in time. The features found in this application that are relevant for my system are:

- Using a quiz combined with reflection triggering questions to make users

think back on their experience.

- Presenting the users with the result to help them see what they need to get better at.

4.4 Implications for my work

In this section a summary of the findings earlier in this chapter will be presented, and also in what way they will influence the system created for this thesis. The games described above are situated in various contexts, with different learning goals. Even so, specific features were found in each one of them that can help promote the objectives of the website created for this system. A summary of which games supported the different requirements that set for my system can be found in table 4.1

Application name	Feedback	Engagement	Learning	Usability	Privacy
Explore!	✓	✓	✓		
KnowSelf	✓		✓	✓	✓
CLinIC	✓	✓	✓	✓	
Medical Quiz	✓		✓		

Table 4.1: Game properties summary

The features from each game that supports the high-level requirements in my system are summarized in this section. These features and qualities was used as inspiration when creating the requirements for my system, which is described in chapter 5.

4.4.1 Feedback

Features:

- Show path followed during an activity.
- Presenting time spent on different activities.
- In-game automated feedback.
- Revealing if the given answers are correct.

As mentioned in an earlier chapter, feedback is important to help students improve their test results. To enable feedback from both system and teacher it is important that the collected information is stored and available. Information is created and stored through the mobile devices that are used while playing the game. Giving the students some kind of feedback during the activity could be interesting, but is should be integrated in a way so that it does not interrupt users to much while playing. It could also be used to make sure players understand the game correctly, e.g. informing them that more than one question can be answered at each question to obtain a higher score. At some point the students will have to know if their answers are correct or not, keeping this information hidden from the users until the game is over could function as a motivational factor.

4.4.2 Engagement

Features:

- Dividing participants into teams.
- Announcing a winner.

The competitive aspect of the game is important to keep the students engaged while playing. Dividing them into teams will makes each group members success dependent on the groups success, thereby leaving each group member with some responsibility to make sure the rest of the group perform. The announcement of a winner will help engage and motive the student by giving them something to strive after. It is important that they know what they have to do in order to reach this goal.

4.4.3 Learning

Features:

- Having a post-game debriefing or reflection session.
- Triggering reflection by using collected data.
- Reviewing mistakes.
- Mini games related to the material.
- Integrating reflective questions in the game.

One of the most important aspects of creating the system described in this thesis is making it easier for young students to learn about our cultural heritage, in this case paintings. A post-game reflection session let students reflect their experience and learn from it. During these kinds of sessions the data collected while playing can be used to trigger reflection. Letting the students know how they did, and enable them to review their mistakes makes it easier for them to see what subjects they need to educate themselves further in, and what they already know. Mini games could be used by teachers to educate students on subjects they find particularly important, e.g. what are the characteristics of paintings created within a given era. For the same reason teacher could also have the ability to add reflective questions that appear during the game to make students reflect on specific elements of a painting.

4.4.4 Usability

Features:

- Visualizing data.
- Explaining the meaning of the presented data.
- Give users information on how to play the game.
- Allow user to play a tutorial before starting the game.

Making the system easy to use is key to the success of this application. It is not a system people will use on a daily basis, and therefore they will not want to spend a lot of time setting it up and figuring out how to use it. During the reflection session a large amount of data will be presented to the students. Visualizing some of this data with graphs and diagrams can make it easier for viewers to understand what the data actually means. Before playing the game, students should also be presented with information on how the game works. This information should be provided by either the teacher or the system itself. Letting user play some kind of tutorial before playing the actual game in a museum could help minimize the amount of time wasted while at location.

4.4.5 Privacy

Features:

- Allowing users to enter incognito mode.

Privacy is a big issue in today's society. Depending on what data the application will collect during an activity, it might be necessary to let users control whether their actions are being logged or not.

Chapter 5

Requirements

This chapter describes the functional- and non-functional requirements for the reflection session, and the website created to support it. The requirements are a result of the findings during the autumn specialization project and the topics reviewed in earlier chapters.

All requirements are rated High, Medium, or low depending on the importance of the requirement.

- **Low(L)** - Requirements are considered to have little or no impact on how the system work and how the experience using it will be.
- **Medium(M)** - Requirements are not essential, but might have an impact on performance, user experience, etc. These requirements are usually down prioritized if the time limit is short.
- **High(H)** - Essential requirements that must be fulfilled before testing the system.

5.1 Functional Requirements

The functional requirements define the functionality of a system. Each requirement should describe a single function and its priority. The requirements listed in table 5.1 applies to the website created for the reflection session.

Requirement Nr.	Description	Priority
FR-1	Website should be able to display team scores	H
FR-2	Users should be able to select what session they want information about	H
FR-3	Website should enable users to view the paintings connected to the current session	H
FR-4	Website should provide the questions related to each painting	H
FR-5	Website should provide the different answers submitted by the groups to each question	H
FR-6	Website should enable the user to browse the augmented objects related to a painting	M
FR-7	Website should be able to fetch updated information at runtime	M
FR-8	Website should support all the best known browsers	M
FR-9	Users should be able to add questions anonymously at any time	H
FR-9	Website should be able to give a visual comparison of the group scores	H
FR-10	Website should scale to various screen sizes (included mobile)	L

Table 5.1: Functional requirements reflection session

5.2 Non-Functional Requirements

A non-functional requirement is a requirement that specifies what criteria that can be used to judge the operation of a system. Keeping the focus on desired qualities of the system rather than specifying what tasks it should perform. Examples are: accessibility, capacity, privacy, stability etc. The sections bellow lists the non-functional requirements for the reflection website.

5.2.1 Usability

The usability requirements in table 5.2 was defined to ensure that the website makes it as easy as possible for the users to conduct their desired tasks while using it.

Requirement Nr.	Description	Priority
NFR-U1	The interface should be intuitive and easy to use	H
NFR-U2	Poor reading skills should not make a user unable to use the site	M
NFR-U3	Guidelines on how to use the website should be provided together with the system	H

Table 5.2: Non-Functional usability requirements for reflection session

5.2.2 Engagement

The requirements defined in table 5.3 was created to keep focus on developing a site that will provide the required information, but also to keep the students engaged throughout the use of it. In addition to keeping the scores hidden until the end of the session, these requirement will help the students stay focused and engaged while going over the data from the game session.

Requirement Nr.	Description	Priority
NFR-E1	The website should contain as little distractions as possible	M
NFR-E2	The website should present information in a way that engages the students	H
NFR-E3	Navigation should be quick and to the point	M

Table 5.3: Non-Functional engagement requirements for reflection session

5.2.3 Availability and Scalability

The requirements in table 5.4 was created to make sure the system has as little downtime as possible, and to design the site so that it will work whether it is being used by a small amount of users or a big group of people playing together in one session.

Requirement Nr.	Description	Priority
NFR-AS1	The system should be available to users at all times	L
NFR-AS2	Website should scale to different session sizes (more groups/questions/paintings should not influence the usability)	M

Table 5.4: Non-Functional availability and scalability requirements for reflection session

Chapter 6

System Design

In this chapter, my system design will be presented. The functionality and design of both mobile application and the reflection website will be described with the use of screenshots and diagrams. The findings in previous chapters used to create the functional and non-functional requirements were used to guide the design of both website and the mobile application. Most of the work connected to the development of the mobile application was done during the fall of 2013, but since it is strongly connected to the website created in this thesis I will present the system as a whole.

6.1 System description

This section describes how the two parts of the system works, and its goals. The first part of the system consists of a game played on mobile devices. Players are located at a museum where they cooperate in groups against each other. The game can be set up to work in any museum or gallery with pictures or paintings, but requires an internet connection to work.

The second part of the system is a website meant to be viewed on a shared screen after having visited a museum. It is presented to the people who have already used the mobile application in order to make them reflect on their experience at the museum. This part of the system also requires an internet connection, since the information used to trigger the users reflection is stored in an online database.

6.1.1 Target Group

The system has been designed for students from the age of 10 and upwards who are learning about art, history, or cultural heritage in school. In a school class the teacher will work as a facilitator, setting up the game before visiting, and guiding the class during the reflection session.

6.1.2 System Dynamics

The application, "musARum", is a mobile augmented reality quiz game to be played in a museum. Players move around in the real world scanning paintings to reveal virtual content connected to them. By telling players what paintings to find, the application guides them through the museum following a specific route. First, players are asked to create questions for the paintings they scan. The trickier the questions are, the harder it will be for following groups to answer them. How these questions are created and answered is further explained in section 6.4. The game is finished when all groups have answered at least one question connected to each painting.

After the museum visit students will have the opportunity to add anonymous questions related to the visit through a website, allowing them to individually reflect on their experience. Following this is a collaborative reflection session taking place in the classroom. This session should happen the following day, while students still have the visit fresh in their mind. Here, teacher and students will be presented with the answers they provided during the visit, the material connected to the different paintings, and a chart showing the group scores.

6.2 Phases

The system consists of two phases, the game phase and the reflection phase. The first phase takes place at the museum, and consists of two sub-phases. In this phase students will participate in a quiz game, and compete to obtain the highest score. The reflection phase takes place after the museum visit and aims to trigger both individual and collaborative reflection. The reason for dividing the game into these phases is that classes usually have a limited amount of time available when going on these visits, and it would therefore be beneficial to not let the reflection session reduce the time students have to explore the museum.

6.2.1 Game Phase

The game consists of two phases, phase 1 where students create questions, and phase 2 where students answer the questions created by the other groups. To start playing the students need a session code provided by the teacher, and they need to enter their group name which can be whatever they want it to be.

Creating questions

After filling in the information required to start playing students are presented with an image of the painting they have to scan in order to create questions. When the painting has been found and scanned using the students device, they can view the related content before creating questions. The challenge in this phase is to create difficult questions so that competing groups will have trouble finding the correct answer. Groups have to submit at least one question to the painting before they are able to continue to the next one.

Answering questions

After the students have created questions, they will be taken back to the menu and can choose to start phase 2. When starting this phase they will be presented with an image of the painting they need to find, just like in phase 1. When they have found and scanned the painting, a list of questions will appear, these are the questions submitted by the other groups in phase 1. For each correct answer the group submits they will get points, but they will not know if their answers are correct or not until the reflection phase.

6.2.2 Reflection Phase

In this section a brief description of the reflection phase is followed by a more detailed rationale of the most important functionality that is implemented in this system. This functionality will be described in relation to the CSRL model presented in section 3.5.4. Out of the four stages of the CSRL model listen bellow, the system created for this thesis mostly focuses on the first three. It can be used to support the fourth stage, but no functionality supporting this specific stage has been implemented.

1. Plan and do work.

2. Initiate reflection.
3. Conduct reflection session.
4. Apply outcome.

Following the visit students have the opportunity to reflect individually before participating in the collaborative reflection session in the classroom. The individual reflection is something students would typically do at home after school. The idea is that students will reflect on their experience, and add any questions they come up with related to the visit anonymously through the website. When the class is gathered in the classroom they will view the website on a shared screen, and review the questions, their answers, and discuss their performance while at the museum. This is also where the winner is announced, and students are presented with a graphical visualization of their score compared to the other groups.

Plan and do work

The plan and do work stage is actually done before and during the game phase, but according to the CSRL model, this is where the reflection cycle starts. How the system supports this stage is shown in table 6.1 The functionality supporting this stage is connected to RQ1 and RQ2, which looks into how mobile augmented reality can motivate users, and how reflection can be improved by collecting data during an activity. The "Work" in this context is the activity the students participate in, the competitive quiz. An issue connected to this was what data to collect, and what data could help trigger reflection. By collecting the data submitted by users, answers and questions, both students and teacher can look back on what was done during the visit and discuss the result of the quiz. Reflection is triggered by the teacher and the students eager to find out how they did on the quiz.

Plan work	• The teacher plans the visit and selects what paintings to include in the quiz, filling in information and images that should be related to the paintings. • A date for the museum visit is set.
Do work	• Searching out information. • Creating questions. • Answering questions.
Monitor work	• The system collects data that can be used at a later time. • Teacher is able to view group answers in real time. • Teacher is able to view group scores in real time.

Table 6.1: CSRL cycle, plan and do work support.

Initiate reflection

The second stage, initiate reflection, occurs after the game is finished. The teacher will inform the students of the upcoming reflection session, and how they have to prepare for it. How this stage is supported can be seen in table 6.2. The outcome of this stage of the cycle will be the frame for the reflection session.

Set objective	• The teacher informs students what the purpose of the reflection session is. • Explains that the winner will be announced during this session.
Involve others	• Teacher informs students that attendance is obligatory. • Teacher tell students how to prepare for the reflection session.
Plan session	• Teacher announces when, where, and how the reflection session will be conducted.

Table 6.2: CSRL cycle, initiate reflection support.

Conduct reflection session

Table 6.3 shows how the system supports the conduct reflection stage. The functionality supporting this stage of the cycle is connected to RQ2 and sub.RQ2 which aims at answering how data can be used and presented to promote reflection. In this system there are several steps characterized as reflection sessions. First, students will conduct an individual session at home to figure out any questions they might have and prepare for the collaborative reflection session. Second, students and teacher reflecting together in the classroom. The outcome of the individual reflection will be the questions created by the students and a state of preparedness for the collaborative session. The outcome of the collaborative reflection session will be change in the form of increased knowledge about the painting, and notes on how to improve their own learning capability for future activities.

Make related experiences available	• Looking at all the answers submitted to the different questions. • Students telling the class how they found information. • Discussing questions that groups had trouble answering.
Reconstruct or envision work experience	• System presenting the answers and questions created. • System showing the paintings being discussed. • System presenting the scores each group obtained. • Student telling others how they found information.
Understand meaning	• System helps students understand context by showing the painting related to the questions. • Helps students understand questions connected to the images related to the painting by presenting them together.
Articulate meaning	• Have groups explain the meaning of questions and answer-alternatives if they are unclear.
Critique experience	• When the data is shown is classroom, teacher and students are able to comment on questions/answers. • Critiquing the difficulty level of questions. • Discussing how relevance of questions. • Teacher being able to critique students based on answers provided to the different questions.

Reach resolution	• Writing down suggestions on how to improve their performance for later activities. • Teacher and students seeing what areas students need more tutoring in.
Plan to apply reflection outcome	• Finding out when and where the suggestions to improve their performance can be applied. • Set a time frame for when students need to have studied the material they are weak in.

Table 6.3: CSRL cycle, Conduct reflection session support.

Apply outcome

The system has no functionality to support this stage of the cycle. Applying the outcome of the collaborative reflection session is up to the teacher and students themselves. Guidelines on how to apply the outcome will be provided in addition to the guidelines concerning the rest of the system.

Functionality supporting reflection

When conducting the **individual reflection** session at home, users is presented with questions created to trigger reflection. By enabling the user to post questions anonymously while reflecting provides material to discuss during the collaborative reflection session, and also helps the user prepare. Seeing all the questions together helps with providing an overview of what students found troublesome during the visit.

In the **collaborative reflection** session users are presented with data to support and promote reflection in various ways. Questions connected to each painting are presented separately together with an image of the painting and the material connected to it. Questions are reviewed one by one, and the answers to each question are displayed at the push of a button. This allows students to keep their focus on one question at the time, and comments or questions can be made before moving on to another question. Questions with a high percentage of wrong answers works as a notification to the teacher, and allows him to clarify any misunderstandings.

The questions posted as a result of the individual reflection enables the teacher to see any other issues connected to the visit, and clear this out as well. Group scores are calculated by the number of correct answers provided by each group, and is presented to the users in bar chart allowing them to see their score compared to the other groups.

Reflection amplifiers

"Reflection amplifiers" refer to deliberate prompting approaches that offer learners structured opportunities to examine and evaluate their own learning. In the paper written by Verpoorten et. al. [37] 35 reflection amplifiers are identified. The list bellow presents the ones that are present in this system:

- Transparent pedagogical rationale - The learners get informed about why this learning activity has been designed for them and how completing it will affect them.
- Annotation sharing mechanisms - The annotations (reflections on the material, notes, summaries...) a learner adds to learning materials are made available to other learners.
- Graphical presentation of contents - Graphic organizers are presented as alternative or complement to textual structure: mind-maps, heuristic schemas, spider webs, contrast matrices, etc.
- Ease of learning / Self efficiency judgment - The learners engage in a self-assessment of their perceived ability for the task.
- Formative assessment - The course offers assessment intended to generate feedback on performance to improve, helping learners to assess their own learning.
- Profiling questionnaire - The course encourages learners to reflect about themselves by filling in a learning profile questionnaire.
- Judgment of learning - Learners are asked to report the progress they believe they made in the learning area as a consequence of having taken the course.
- Questions generation - Learners are invited to post questions about the material for which they receive a feedback.
- Explicit reflective activities - The course includes self-reflecting activities encouraging student to analyze various aspects of their performance.

- Test debriefing - Learners are formally invited to question their own results and to analyse successes/failures, strengths/weaknesses, areas to review, errors or misconceptions.

These reflection amplifiers were identified by Verpoorten in relation to online courses. The system created for this thesis can be considered a hybrid as it utilizes both traditional classroom tutoring as well as online tools. Therefore a selection of the amplifiers identified by Verpoorten was selected and applied through functionality in the system, or described in the guidelines created for the teacher.

Reflection session process overview

To expand figure 3.1 which presents the mobile application game flow, figure 6.1 shows the flow of the post-game reflection session and how it connects with the game. It also shows what activities are related to the different steps in the MIRROR CSRL model in figure 3.3.

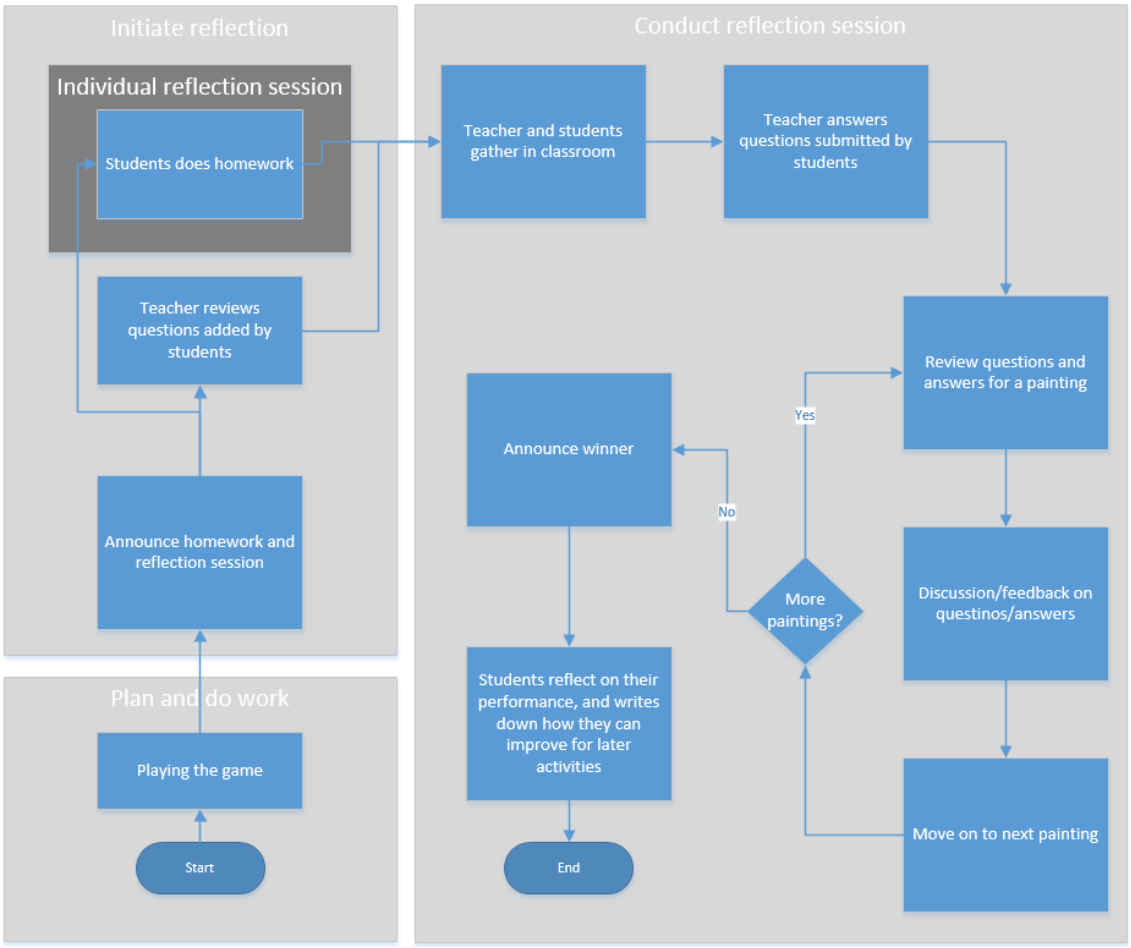


Figure 6.1: Showing the post-game process.

6.3 Scenario: Museum visit and reflection session

The following scenario is a continuation of the one written during the Computer Science specialization project fall 2013, and will expand it to cover the post game reflection. It is written using the guidelines provided at usability.gov [38]. The purpose of this scenario is making it clear who the users are, how they end up using the system, give an example of how the game session may progress, and how the reflection sessions can be conducted. The part most relevant for this thesis is the post-game activities, but the whole system will be covered to create an understanding of how it is all connected. The following scenario follows one

group through the game session, the individual reflection, and the collaborative reflection session.

6.3.1 Museum visit

A class consisting of 25 high-school students have arrived at Trondheim kunstmuseum, where their teacher Jonas have brought them on a class field trip. They have been divided into eight groups, and each group have at least one device with the application installed. Kim, Ola, and Kari were put in one group and decided to use Ola's iPad since it has a bigger screen. While located at the museum entrance, Ola starts up the muARum application that he was told to install on his iPad the day before. When the application has started up and the main menu is showing, he inputs the session code '336' that Jonas shared with the students. Kari and Kim come up with the name "Eple" for their group, which Ola also typed into the applications user interface. When instructed by the teacher, Kari tapped the button labeled "Phase 1" on the iPad, and an image of the painting "Skip i storm" by Daniel Melbye appeared on the screen along with the text "Find a painting called 'Skip i storm'". The group walks through the museum, and after a few minutes Kim spots a painting on the wall that matches the image on the iPad. Another group had stopped on the painting next to this one, and where pointing their device towards it. Ola taps the button labeled "Scan picture", and the iPads camera activates. He points the camera at the painting, and after a few seconds augmented text and images appear on the display along with a button for creating questions. After looking at the augmented elements for a few moments, the group proceeds by tapping the "create question" button. They fill in question details based on the information they got from the augmented elements, and also adds a question based on some information Kim found after googling the painting. After submitting the questions, Ola tapped the button labeled "Continue". A printing called "Paa kjaerlighetens bolger" by Edvard Munch appeared as the next painting on their route. musARum took them through a route consisting of 11 paintings where they inspected information and created one or two questions for each one.

The whole class shared a lunch break at "Cafe ni Muser" next to the museum, discussing their impressions so far. Jonas appeared to be inspecting their progress on his laptop, and took some groups to the side to give them feedback. After the break, the group member of "Eple" logged in to musARum once again and clicked the button labeled "Phase 2" on the main menu. The painting "Skip i storm" appeared on the screen once again, and the group went over to the location where they previously saw it. The painting was once again scanned using the iPad, but this time a list of questions created by the other group earlier in the day appeared.

The first ones where easy to answer after having read the augmented text, but further down the list they found a questions that neither of the group members could answer. Using their phones they searched the internet for an answer, and quickly agreed on what they should submit as their answer. The process continued through the same 11 paintings the group has previously visited. After 90 minutes all groups had finished and was called out to the bus that was taking them back to school. While still on the buss Jonas announces that the homework for tomorrow will be to visit the link he has sent them via e-mail, and answer the questions there. He also tells students to post any questions they have related to the visit via that link.

6.3.2 Reflection

When Kim gets home, he checks his e-mail and sees the mail from Jonas. Before opening the link, Kim goes to the kitchen to get something to drink while answering the questions. He takes his laptop up to his room, sits down by the desk, and opens the link. He starts reading through the questions, and answering them one by one. When getting to the third question, Kim leans back in his chair to ruminate before submitting an answer. The question he is trying to answer is: Has your earlier understanding of any concepts changed in the light of the museum visit? He remembers being surprised about recognizing Munch's paintings without having seen them before, and notes down how this changed his perception of different artists. He also submits a question, asking how the different painters end up with their own style. He answers the rest of the reflection questions, and submits another question regarding one of the augmented images before considering himself done with the homework.

The next day the students gather in class where Jonas has prepared the projector. Earlier that day Jonas has read through the questions that were posted by the students while doing their homework to make sure he can answer all of them. He brings up the list of questions on the projector so that the whole class can see them. He starts going through them, answering the ones that has been posted by more than one person first. When all the questions has been answered Jonas clicks the link to the first painting on the route. All the questions created for the painting called "Skip i storm" appears together with an image of the painting and the augmented material related to it. Kim, sitting together with Ola and Kari, sees their question in the list and is excited to see how many has answered their question correct. Jonas starts by revealing the answers given by the groups for the question at the top of the list. It was a question where the answer could be found in the augmented text, and all groups have provided the correct answer. Jonas compliments the class, and moves

on to the next question. This is the question created by the "Eple" group where Kim found information online to make it hard for the other groups to answer. Before revealing the answers, Jonas makes a remark saying that this is a tricky question. He presses the "Show answers" button, and all the answers are shown. Most of the groups have provided the correct answer, but not all of them. Jonas asks the "Eple" group to tell the rest of the class where they found the information to create this question. Since Kim was the one who searched out the information, he is the one to answer. Kim tells the class that he searched for the painting on Google and found information about the painting on wikipedia. A member of another group raises his hand to speak and argues that their group found information on another website which said the answer was something else. Jonas explains the importance of finding sources you can trust, and that pages like wikipedia can contain incorrect information. Even though the other group has found information that contradicts what Kim had found, Jonas confirms that the information Kim searched out is correct and continues to the next question. After having repeated this process was repeated for all 11 paintings, Jonas told the class that it was time to announce the winner. The whole class got excited and seemed eager to know the results of the quiz. Jonas opened up the page revealing all the group scores. Ola quickly found their score by looking at the poll labeled with the name "Eple", and was kinda disappointed when he saw that the poll of another group raised higher that theirs. Jonas announced the winner, and applause was given by rest of the class. When the class had settled down Jonas wrote some questions regarding their experience on the blackboard, and told the class to answer them and keep the answers so they could be to help the next time they engage in a similar activity.

6.4 User Interface

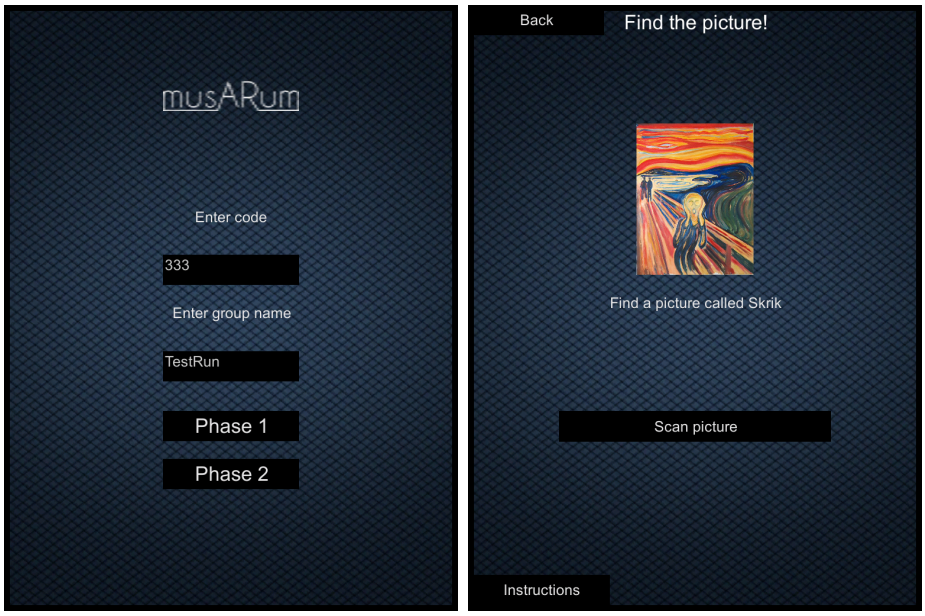
In this section the user interface will be presented. Screenshots of both mobile application and website will be used to help illustrate. Since the mobile application and website have completely different interfaces, this section will be divided into two subsections, one describing the mobile application, and one describing the website.

6.4.1 Mobile Application

When designing the interface for the mobile application is was important to consider the varying screen sizes on handheld devices. Therefore everything in the user interface was programmed to scale according to screen size.

Main Menu

The main menu is the first screen a player sees when starting the application(see Figure 6.2a). It lets the user input the session code provided by the teacher, and a group name through text fields. Pushing the "Phase 1" button will start the game, and take users to the next screen. The "Phase 2" button will not do anything until the user has completed phase 1.



(a) Main menu. (b) Instructions

Figure 6.2: Screenshots of the main menu and instructions screen.

Instructions / Task

After starting either "Phase 1" or "Phase 2", the user will be presented with an instruction screen(see Figure 6.2b). Here a preview of the painting to be found is displayed, as well as the name of the painting. Pushing the button labeled "Scan picture" will turn on the devices camera, and let users scan the painting. Pressing the button labeled "Instructions" will make a textbox with instructions on what the person using the application needs to do. Persons running the application on an iOS device will see a button labeled "Back" in the upper left corner. This button will take you to the previous screen. Persons using an android device will not see this button since the "back" button is integrated into the hardware on devices running this OS.

Augmented Reality View

After pushing the "Scan picture" button, the camera will start up. To indicate to users that it is looking for a painting to recognize, a thin line moves up and down on the screen. When the camera has detected a painting, the user will be able to see the information connected to it. An example of this can be seen in figure 6.3. It is designed so that textual information connected to the painting will show on the left side, and related images will appear on the right side.

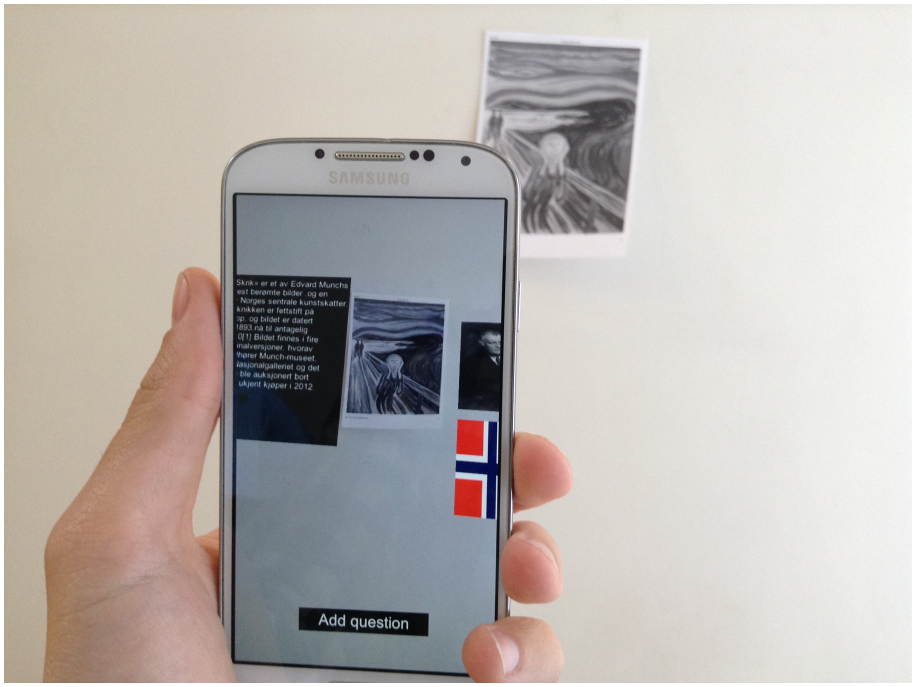


Figure 6.3: Showing how the information is presented through augmented reality

If the game is in its first phase, phase 1, a button labeled "Add questions" will appear. Pressing this button will bring up textboxes where users can fill in their questions together with one correct answer, and 3 incorrect alternatives. This can be seen in figure 6.4. After a question has been submitted a button labeled "Continue" will show. Pressing this button will take the user back to the instructions screen, and instructions on what painting to find next will be given.

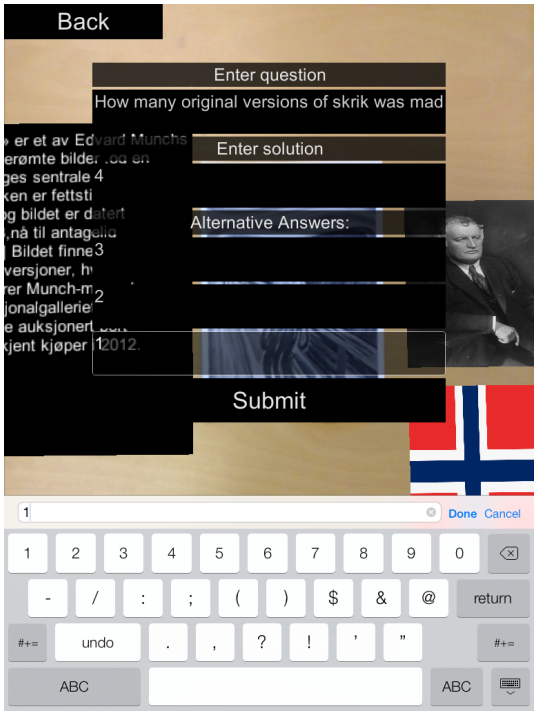


Figure 6.4: Screenshot of how to create a question

When playing the second phase of the game, phase 2, the interface will look different. A button labeled "Questions" will appear after scanning the painting. Pressing this button will bring up a list of the questions added by other groups as shown in figure 6.5a. Answering these questions is done by selecting the question you want to answer, and then pressing the "Answer selected question!" button located at the bottom of the list. Pressing this button will bring up a view of the question, and its answer alternatives. How this list looks can be seen in figure 6.5b. Users select the answer they believe is correct by touching it, and then submit the answer by pressing the button labeled "Submit answer!" located bellow the list of alternatives.

(a) Selecting. (b) Submitting.

Figure 6.5: Interface for selecting which question to answer, and submitting answer.

6.4.2 Web Application

The web application supporting the reflection session has been designed to be used on a shared screen in front of a class full of students. The site consists of two parts, one where students can add anonymous questions related to the visit, and one used during the collaborative reflection session.

Reflection site

The reflection site, or the home screen, is where teachers and students can browse group scores, questions created for the different paintings, what answer the groups has given to these questions, an image of the painting itself, and the images connected to the painting. To see this information the user first have to enter the session ID, this is the same code as the one required to play the game. After entering this code, a diagram showing the score obtained by the different groups will show. See figure 6.6. By pressing the links on the left side of the website, user can navigate between the different paintings found in the current session.

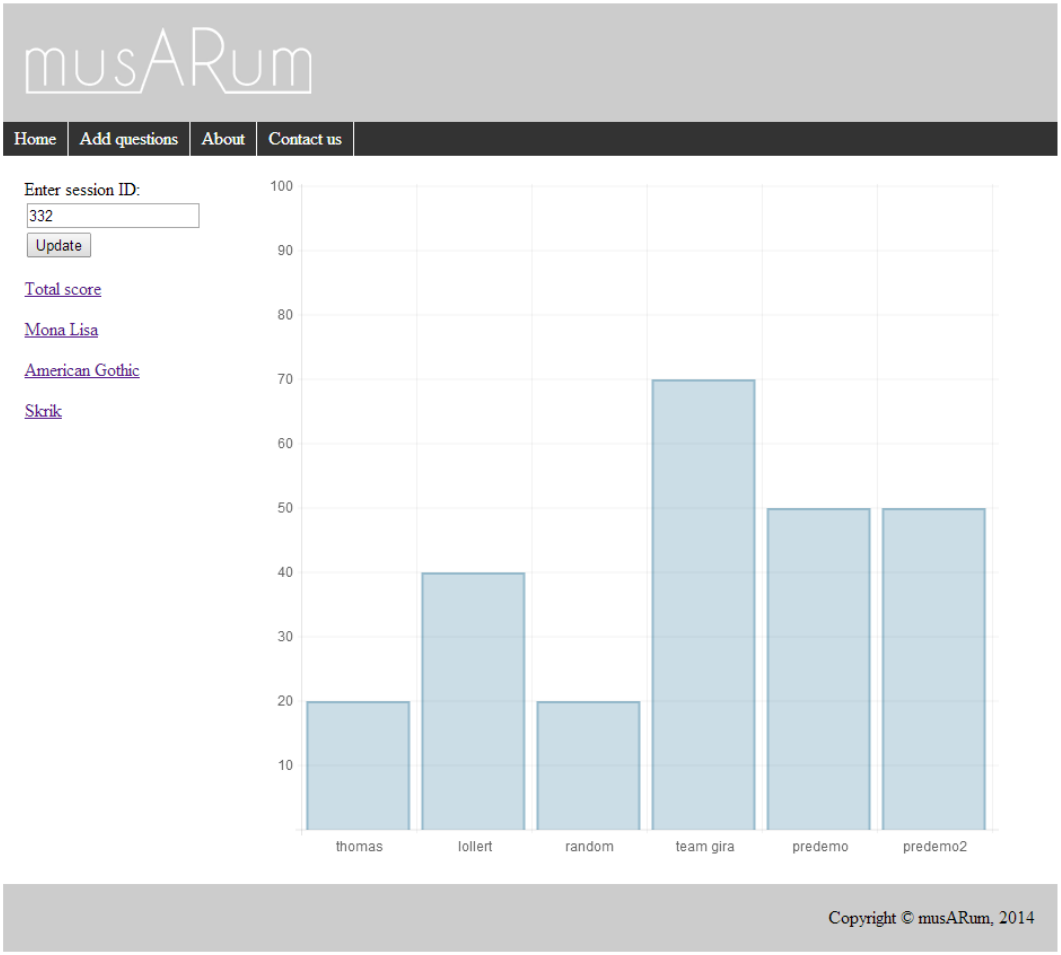


Figure 6.6: Screenshot of score chart

Clicking one of these links will present the user with a list containing all the questions created for that specific painting. Each question has a "show answer" button connected to it, pressing this will reveal all the answers submitted for that question. On the right hand side students can also see an image of the painting and the images connected to it, making it easier for students to remember the visit.

Question site

Following a museum visit students might have questions they did not have time to ask, or are embarrassed to ask in front of others. For this, the website has a section where students can add questions anonymously before taking part in

the collaborative reflection session. To add a question user simply click the "Add questions" button in the navigation bar. This will take them to a site consisting of a textbox to fill in their question, a submit button to submit their question, and a list of all the other questions that have been submitted. See figure 6.7 It is important that students enter the correct session ID before submitting the question, or else the teacher will not be able to find it.

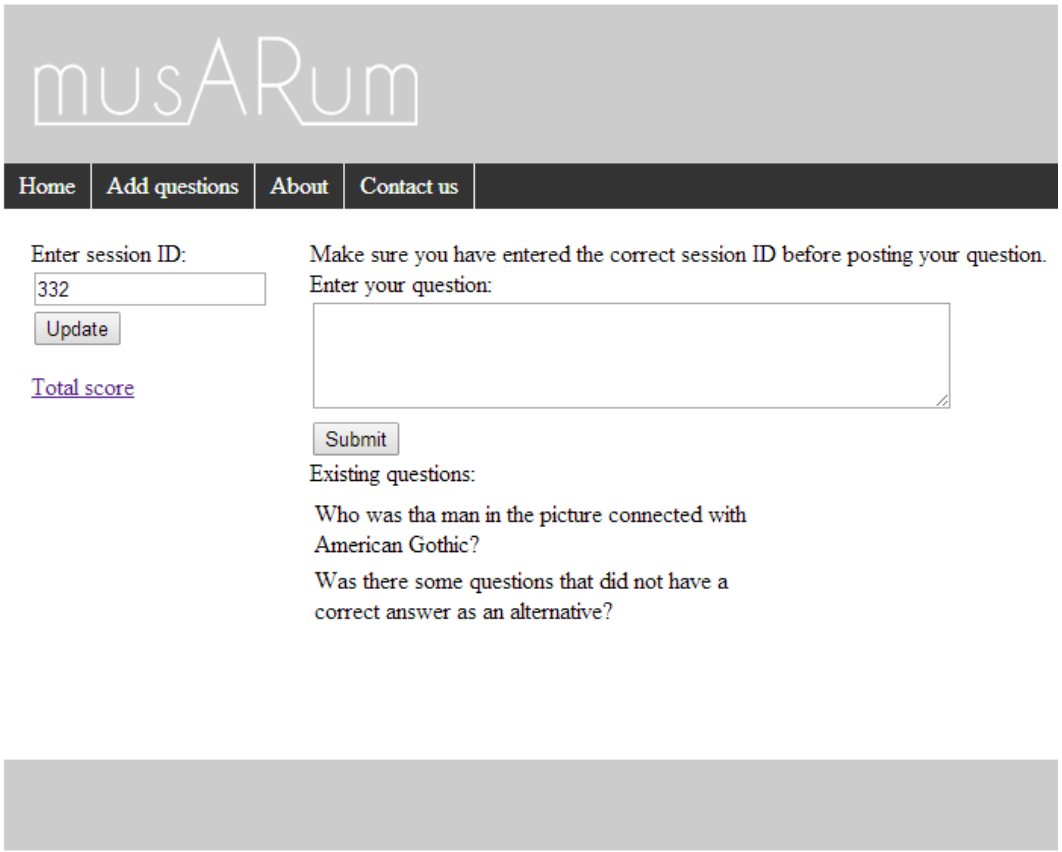


Figure 6.7: Screenshot of how students can submit questions

Chapter 7

Technical Description

The system described in this thesis consists of a cross-platform mobile application, a web application, a MySQL database, and the Vuforia imagetargets database. To play the game users need a code that is generated when a new session is created. A session contains links to all the paintings included in the session, painting IDs to connect them to the Vuforia database, links to augmented images, and the information used for the augmented text. As of now this is done by manually editing the MySQL database.

As the game utilizes augmented reality to provide the users with information it required some way of recognizing and tracking the paintings using a mobile device. This functionality was implemented using the Vuforia SDK [1] which provides an easy way to develop apps that can "see" and recognize the world using a camera. The development environment used to create the app was Unity [2]. Unity is a game development ecosystem that provides the developer with tools to create interactive 2D and 3D content, allowing me to easily place augmented object where I wanted them to be in relation to the paintings. The images of paintings to recognize is stored in the Vuforia database, everything else is stored in a MySQL database hosted on my server. PHP scripts are used for fetching, updating, and inserting data from both mobile application and website. The website was created using PHP, HTML, and Javascript. An overview of how the different components of the system is connected can be seen in figure 7.1.

[1] https://www.vuforia.com/
[2] https://unity3d.com/unity

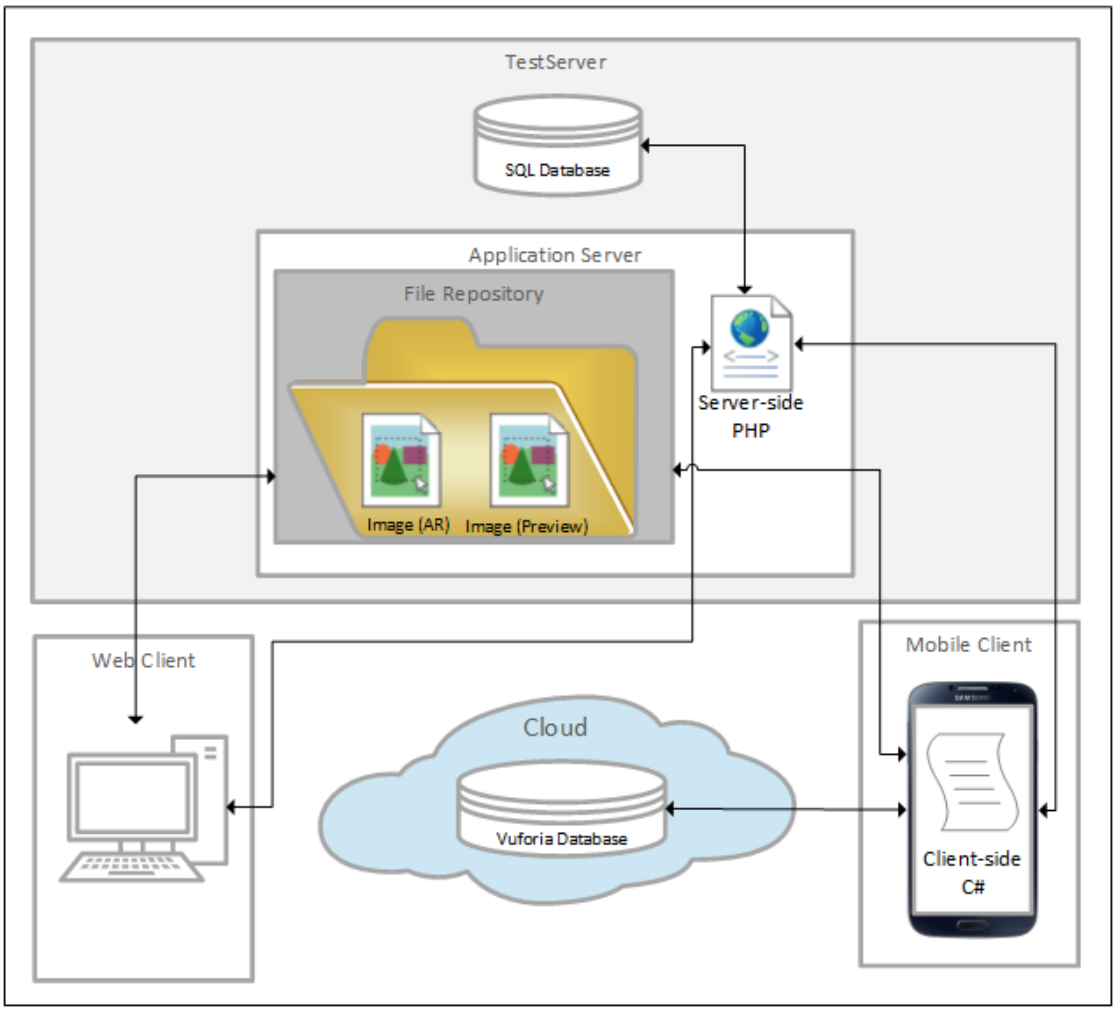


Figure 7.1: An overview of the communication between system entities.

7.1 Technological choices

This section presents the technologies used to create the game, and also a brief grounding of my choices.

7.1.1 Unity

As 91.1% of the worlds mobile devices runs either iOS or Android [39] it was important make the application available on these platforms. To be able to run a user evaluation with a full class, the application needs to support their phones and

tablets since I only have access to a limited amount of devices. Unity supports all the major platforms which enable users to install and use the application on almost every smartphone available today. It also provides an interface that eases the process of working with 3D objects. Coding is done in Javascript, C#, or Boo. As C# is my language of choice and also the language I have the most experience with, the decision was easy.

7.1.2 Vuforia

The Vuforia SDK makes it possible to build vision-based augmented reality applications for iOS and Android. It uses image recognition to detect and track images and simple 3D objects. It positions the virtual objects in relation to the real world images captured through the device camera and updates its position in real time. Vuforia also provides a Unity extension. Using this extension allows developers to build augmented reality applications that are cross-platform compatible. Instructions on how to install and use the extension is available on their website[3] where the documentation is available as well. Vuforia is free to use, but only provides free users with a limited amount of image recognitions per month. The amount of recognitions available for free was more than enough to develop, test, and evaluate the application described in this thesis.

7.1.3 PHP and Javascript

The reflection website was developed using HTML5, PHP, and Javascript. PHP was used to communicate with the database to calculate scores, get image URLs, and to submit questions. The reason for using PHP was it has a light-weight syntax and enabled me to quickly create and alter aspects of the website following the tests and evaluations that were conducted. Javascript was used to create the score graph presented to the students during the reflection session. The graph is created using Chart.js [4] which utilizes HTML5 to create a lightweight and good looking experience for the viewers.

[3] https://www.vuforia.com/
[4] http://www.chartjs.org/

Chapter 8

Usability Study

In this chapter I will present how the usability testing was conducted, and in what ways it affected my work. The tests was conducted in order to find any critical flaws in the system before having it evaluated by an expert and tested in its intended environment.

The usability test was conducted with four participants with under-average to average technical skills, and no one working with or studying IT. The most recent version of the system was used when testing the system. The test subjects used an iPad mini, Xperia tablet Z, or a Samsung Galaxy S4 when testing the mobile application, and a 15" MacBook with Google Chrome installed when testing the website.

During the test I took notes if the users had any problems or concerns related to the system. After testing the system, users were asked to answer a System Usability Scale [40] questionnaire to measure user satisfaction. Then they were asked to fill inn the questionnaire found in Appendix A regarding the difficulty of completing the tasks they were given during the test. And at last they were encouraged to suggest improvements to the system or its design.

8.1 Context

The usability test was set up to simulate a museum visit. Images of paintings were printed out and hung on the walls in a room at Gløshaugen campus to simulate being in a museum. The usability test was conducted to uncover any bugs or issues with the system or its interface, and to ensure the whole process would work as planned when tested with users that has no previous experience with it.

The feedback from the usability test was used to further develop and improve the application and the reflection website before testing the system in a realistic environment with actual students.

8.2 Participants

As mentioned earlier, four participants took part in the usability testing. For medium-large projects it has been found that the highest ratio of benefits to costs is achieved for 3.2 test users and for 4.4 heuristic evaluators [41]. Even though cost was not an issue while testing this system since all the testers were volunteers, four participants should be sufficient to uncover any major flaws.

To mimic the target group in a best way possible, none of the participants had any extensive knowledge about software development or art in general. Responsibilities of participants were to complete the tasks presented to them while thinking out loud. Also, they were asked to provide feedback regarding the usability, design, and engagement of the system after finishing the tasks.

8.3 Procedure

The usability testing was conducted in four separate sessions taking place in private rooms on campus, and in some of the participants private homes. They could choose if they wanted to use their personal device while playing the game, or if they wanted to use a provided device with the application pre-installed. To create the illusion of being in a museum, paintings was printed out on paper and hung on the walls. Before starting, the participants were briefed on how the system works, and how the usability test would be conducted. They were also told that at least one question and answer would have to be submitted to each painting before moving on to the next one, but that they were free to add/answer more if they wanted to. When participants had started the application on their device, they were given tasks to complete, and were told to inform me, the observer, when they had completed this task. Their interaction with the application was closely monitored while they solved these tasks. After finishing the game on their mobile device they were also given tasks to perform on the accompanying website.

After all tasks had been attempted, the participants was asked to fill in the system usability scale questionnaire (see appendix B), fill in the task related questionnaire

(see appendix A), and to give general feedback based on their thoughts after using the system.

8.4 Tasks

When creating the tasks used for the usability testing, it was important to make sure they covered the most critical parts of the system. All the participants were asked to perform the same tasks. Since they did not complete the tasks simultaneously, the first participants would not have had any questions to answer. Therefore some data was generated prior to the testing to enable them to complete their tasks.

The tasks were divided into two parts. The first part was tasks that required the participants to use the mobile application. For the second part they were asked to use the website. Before both parts they were given the information they needed to use the system, and was asked to not do anything before they were told to do so.

8.4.1 Part 1 - Mobile application

1. Fill in the needed information and start the game.
2. Find the described painting and create a question.
3. Complete Phase 1.
4. Start Phase 2 and answer the questions for the first painting.
5. Complete Phase 2.

8.4.2 Part 2 - Website

1. Add a question connected to the quiz via the website.
2. Find and browse the questions created for a painting of your choice.
3. Find out what score your group achieved.

8.5 Metrics

The usability metrics define how the user performance is measured. To measure the users performance, these metrics was defined:

8.5.1 Task success rate

Each task requires the user to navigate the interface or input specific data to reach their goal. When the user believes s/he has achieved the goal, the task is noted as completed. Whether the task was successful or not depends on if their achievement corresponds with the goal of the given task. If the user believes s/he has completed the task, but in reality has not achieved the goal, it will be noted as an error and effect the overall success-rate in a negative way.

8.5.2 Error rate

An error is noted if the user is not able to complete the task s/he is given. This also implies that if a user has to ask for help, an error has occurred. The user might not be aware that an error has occurred, but their actions will result in an incorrect outcome. Each instance of an error will be noted along with a description of the action.

8.5.3 Users subjective satisfaction

The opinions of users regarding the difficulty of the tasks, system design, system functionality, and its ability to fulfill its goals was collected. They were also encouraged to suggest changes they thought would improve the overall experience while using the system.

8.6 Goals

The main goal of usability testing the system was to uncover any critical flaws before conducting a user evaluation. Because of the limited amount of time and resources available to test this system, the user evaluation will only be conducted one time. This means that if something fails during the evaluation, there will not be enough time to evaluate it a second time. Also usability testing the system

will help in identifying potential design issues that should be addressed to further improve the end-user satisfaction. These objectives was defined to ensure the desired goals of the testing was achieved:

- Identify issues related to the design or functionality in the system.
- Determine whether new users are able to use the system without more than the basic instructions.
- Establishing user-satisfaction levels.

8.7 Results

In this section the results from the usability testing will be presented. The findings in this section were used to improve and further develop the mobile application and the reflection website. The results include task success rates, SUS score, difficulty assessment, and feedback from the participants.

8.7.1 Task Success Rate

The task success rates seen in table 8.1 were based on the user's ability to achieve the goals defined for the task without needing help. If a user is unable to complete a task or has to ask the facilitator for help, the task is considered a failure.

Participant	Task 1.1	Task 1.2	Task 1.3	Task 1.4	Task 1.5	Task 2.1	Task 2.2	Task 2.3
1	✓	✓	✓	✓	✓	✓	✓	✓
2	✓	✓	✓	✓	✗	✓	✓	✓
3	✓	✓	✓	✗	✓	✓	✓	✓
4	✓	✗	✓	✓	✗	✓	✓	✓
Completion Rates	100%	75%	100%	75%	50%	100%	100%	100%

Table 8.1: Task completion rate

The tasks in part 1, see section 8.4.1, had a varying completion rate. Task 1.1 and 1.3 was successfully completed by all participants, task 1.2 and 1.4 was successfully completed by 3 out of 4 participants, and task 1.5 was completed by 2 out of 4

participants. The low completion rate on task 1.5 was caused by a bug in the application that trapped users in an infinite loop, and therefore made it impossible for them to complete phase 2 of the game. The errors in task 1.2 and 1.4 was caused by users not understanding what input was required by the application, and indistinct elements in the user interface.

Tasks 2.1 to 2.3, described section 8.4.2, was successfully completed by all the participants.

8.7.2 System usability scale

The results of the system usability scale (SUS) yielded an average score of 73.5 points. Answers can be seen in table 8.2. A score of 73.5/100 is considered to be above average and a good score [42].

The majority of participants did not think they would use this system on a regular basis, but they all argued that this was because they rarely visit museums. No one found the system to be unnecessarily complex, and most found it easy to use. When asked if they thought they would need the support of a technical person the participants were split. The ones who thought they would need help argued that if the application contained more instructions on how to play, assistance would not be necessary. The majority found that the various functions in the system were well implemented. 2 out of 4 participants thought there was too much inconsistency in the system. These were the same users that experienced a bug in the application that caused them to get stuck. All of them thought most people would be able to learn and to use this system very quickly. One person found the system a little cumbersome to use, and no one felt unconfident using it. 3 out of 4 did not feel needed to learn a lot of things before using the system.

8.7.3 Difficulty assessment questionnaire

The difficulty assessment questionnaire was conducted to see how difficult the participants found the tasks they were given during the usability test. After completing all the tasks and finishing the SUS questionnaire, they were asked to rate the difficulty of the tasks they had attempted. Each task was rated on a scale from 1 to 5:

1. Very Easy

2. Easy
3. Normal
4. Hard
5. Very Hard

The results collected from the test can be seen in Figure 8.1

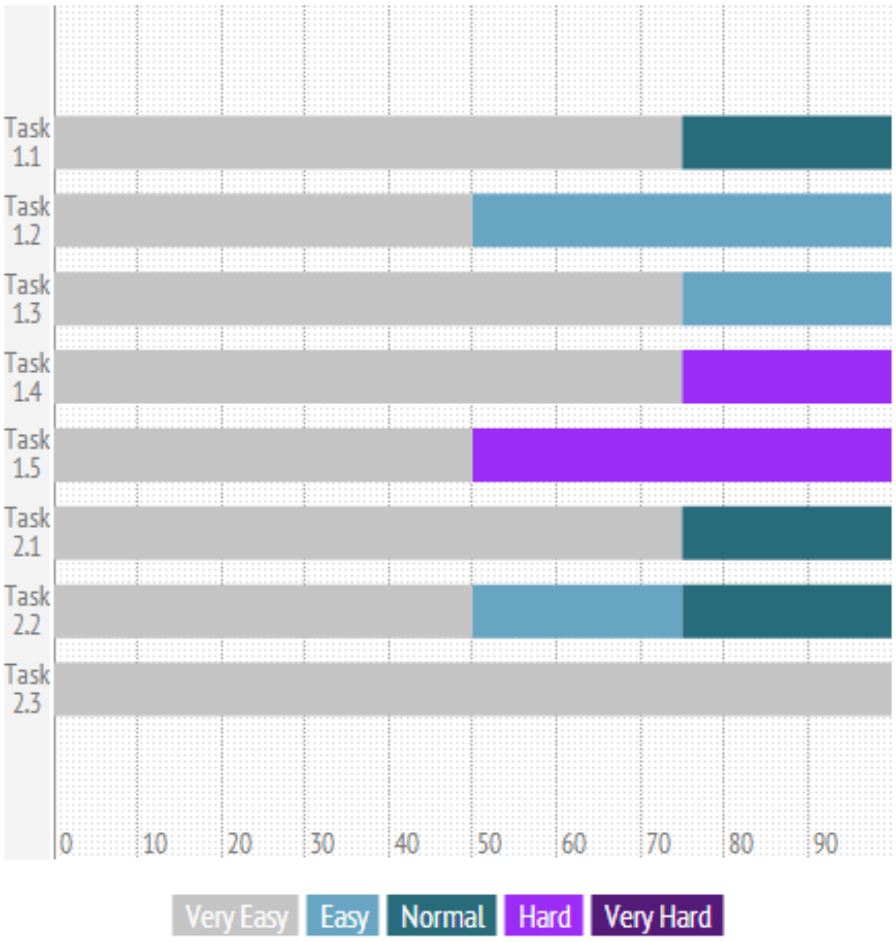


Figure 8.1: Task difficulty level rated by participants

8.7.4 Feedback and comments

At the very end of the usability test users were asked what they liked most, what they liked least, and if they had any suggestions for improvements in the sys-

tem.

The feedback was mostly positive, and the participants seemed surprised that the system was actually fun to use. The most common comment among the participants was that they wanted some kind of instructions on the main menu so that they knew when to start each phase, what input fields was provided by the teacher, and what fields they had to come up with by themselves. Even though these instructions were given by the teacher before starting the game, they all felt it would be useful to have access to them in case one did not hear what the teacher said. Another issue that was pointed out by multiple users was the interface for selecting and answering questions. Some of the participants did not see the button at the bottom of the list, and argued that the color of the button should be changed. They all thought the website was simple and orderly, only commenting on how the text size would look on a shared screen.

Some participants also suggested functionality they thought could help make the system better. To make the announcement of a winner one participant suggested making some kind of visual podium with music and applause in the background. Another suggestion, and perhaps the most interesting one, wanted the user to be able google the paintings and augmented objects by tapping them. Meaning that if a user taps the painting, a browser will open up and show a google search for the appropriate painting.

Most liked

The one thing that fascinated the participants the most was the augmented reality text and images. They all livened up after scanning the first painting, and immediately found the system more intriguing. The graphical representation of the scores also got a lot of positive feedback.

Least liked

Participants disliked the dark colors used for the interface, and missed more in-app instructions on how the game worked.

8.8 Implications for my work

The usability study described in this chapter uncovered a few bugs in the system that had to be fixed before conducting the user evaluation, and also helped me see

what part of the system that can seem confusing to a new user. The bug causing players to end up in a loop between two of the paintings was a huge flaw, and was critical to get fixed before the user evaluation. Changing the color of the button used to select and submit answer should be done to avoid confusion, and the text size of the website had to be increased to make it easier for people to read the information on a shared screen.

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
I think that I would like to use this system frequently		2	1	1	
I found the system unnecessarily complex	1	3			
I thought the system was easy to use			2	1	1
I think that I would need the support of a technical person to be able to use this system	2			2	
I found the various functions in this system were well integrated			1	2	1
I thought there was too much inconsistency in this system	2		2		
I would imagine that most people would learn to use this system very quickly				1	3
I found the system very cumbersome to use	2	1		1	
I felt very confident using the system			2		2
I needed to learn a lot of things before I could get going with this system	3		1		

Table 8.2: System Usability Scale

Chapter 9

Expert Evaluation

In this chapter I will explain how the expert evaluation was conducted, the feedback I got from the evaluator, and how it affected my work.

9.1 Overview

The expert evaluation was conducted with a high school teacher of art history and literature. She was asked to be the evaluator due to her involvement with the testing of the earlier version of the system called MagMAR. This leaves her with an idea of how these kinds of systems actually work when used in their intended environment.

The evaluation was conducted using a Skype video conference. Before the video conference, the teacher was presented with a video showing a full walkthrough of the system and its functionality. The conference was recorded, and data was collected through an interview and general feedback from the evaluator.

The evaluation started with me clearing up any questions the evaluator had after watching the video, and then continued with the interview I had prepared. The interview consisted of 14 questions regarding her opinion and thoughts on the different aspects of the system. Some questions were answered with a simple and short answer, and some evolved into minor discussions. Some of these discussions resulted in suggestions on how to improve the system, and how the guidelines on how to use it should be defined. The evaluator also commented on how the system met the problems uncovered in the earlier version of the system.

9.2 Overall Feedback

The evaluation left me with the impression that the evaluator was satisfied with the system and its intention. At the point of evaluation, most of the systems functionality was implemented, the missing parts were explained thoroughly. The evaluator stated that she had no problem with seeing the usefulness of the system, and that she would be interested in using it for teaching her students. The process of the game (2 game phases, individual reflection as homework, reflection session) she thought was good, and agreed that the system has the potential to provide students with academical gain.

She pointed out that for her to be able to use it on a regular basis to evolve students learning abilities it needs to be more flexible. Due to the limited amount of time allocated to field trips in each class it would have to be used in more than one class. Making the application able to recognize 3D objects could help improve its flexibility, and expand its field of application.

When asked if the system could be useful without visiting a museum or a similar place she emphasized that it is important for the students to go out and see the real paintings. Pointing out that the atmosphere in a museum is very different from the classroom, and that its good to bring students to places they normally would not visit. And that this would help them learn about the museums as well.

The question on how to motivate the students to participate in the reflection session is not an issue according to the evaluator. She stated that as long as the students have fun while playing the game, they will also be interested in participating in the reflection session the next day. The important thing, she said, is that the session takes place the next day, and not the next lesson which might be the week after.

9.3 App Specific Feedback

The biggest change in the app itself compared to the one the evaluator had tested out earlier is the use of image recognition. She thought this to work better than the use of QR-codes since it allows students to keep the painting in focus while reviewing the material, and also said it would allow students to find the painting they were looking for quicker than with the earlier system.

She also believed that the app collects a sufficient amount of data, but is not sure whether it should include links to where they found information or not. This data would be useful to have during the reflection session, but it might be better if the

students explained how they searched out the information instead of just providing a direct link.

9.4 Website Specific Feedback

The evaluator liked the website, and the idea of using it for a reflection session. Opposed to MagMAR where there was no post-game activity. She pointed out that it is important to have a teacher guiding the collaborative reflection session, but that he/she should not control the discussion too much. The information connected to the paintings by the teacher when creating a session should also be available, this will allow discussions around why they did or did not use this information while creating questions.

9.5 Suggestions

During the discussions with the evaluator she identified some features she thought was missing, and some features that could be changed.

9.5.1 Homework questions

Allowing the teacher to define some questions that students have to answer as their homework instead of the reflection triggering questions that is there to help the students think back on the activity. By letting the teacher define questions, s/he can ensure that students search out and learn what s/he wants them to learn about the paintings. Giving them questions to guide them towards correct reading of the picture, and obliging them to search out what is important.

9.5.2 Storing notes

Following the reflection session students will have notes regarding their performance and learning strategies that they will want to look at before taking part in a new quiz. Storing these notes in the system instead of writing them down in a notebook or something similar could be useful to ensure that they have them available before the next session.

9.6 Implications for my work

The expert evaluation helped me confirm that the system is ready to be tested with real users, and made in more clear what parts of the process has to be followed to the letter and what parts teacher and students can improvise with. This information will help define how the guidelines created for the teacher should look. The website supporting the individual reflection should be changed so that the teacher can add questions instead of having predefined questions to trigger reflection. This is to ensure that students search out and read the information the teacher finds important. The information that students see together with each painting should also be available during the reflection session so that students and teacher can discuss why/why not students used this information while creating questions.

The evaluator also suggested that the website should include functionality that enables students to store notes after completing a reflection session for one activity, and be able to read these before partaking in a new activity. This will require some work since the system as of today does not support individuals to login. Because of the limited amount of time available before the user evaluation, this functionality will not be implemented, but instead added to the future work section together with 3D object recognition.

Chapter 10

User Evaluation

In this chapter I will explain how the user evaluation was conducted, who participated, and how it was set up before presenting the results of the evaluation. Due to illness, the class I had planned to evaluate the system with was not able to partake in the evaluation. Luckily I was able to find another school that was interested in testing my system, but because of the short notice and the limited time I had left before the deadline of my project I was not able to evaluate the part of the system which included the individual reflection.

The evaluation was conducted with 51 students from an elementary school in Bœrum, Norway. The school was able to provide each student group with an iPad which I had installed the latest version of the application on before handing them out to the students. The classrooms were equipped with a computer and a projector, so all the equipment needed to conduct the evaluation was in place.

During the evaluation I did not intervene in any way, except to help students or the teacher with any technical problems. To gather data from the evaluation I took notes and observed the participants behavior during the game activity and the reflection session. Also both students and teacher was asked to answer a questionnaire regarding the whole system after having completed the reflection session.

10.1 Context

The evaluation took place at an elementary school is Bœrum, Norway. To simulate a school excursion the images that the teacher had chosen for the quiz were hung on the walls in the schools hallways and classrooms. The images was spread over

a wide area so that the student groups did not have to stand on top of each other.

Before the evaluation itself the teacher participating in it were given a brief introduction to the system and how it works, and was also provided with the supervisor guidelines found in appendix C. The teacher was also asked to find the images and information he wanted to include in the quiz so that the session could be set up. The teacher decided to use images of literature for the quiz, and to only provide the students with very basic information so that they would have to search out information themselves to create difficult questions.

Since the schools entire 6th grade was going to participate in the evaluation, it was decided to split them into two groups. One group tested the system before lunch, and one after. This was to make it easier for me to observe the students, and also to limit the amount of chaos in the schools hallway. Before giving the students the codes they needed to start the quiz, the teacher connected his iPad to the projector and quickly showed them how to create questions during phase 1 of the quiz, and how to answer them during phase 2.

10.2 Participants

The participants in this evaluation were an entire 6th grade at an elementary school and one of their teachers. The students at this grade are 11-12 years old, and their knowledge on the subject of the quiz should be around the same level. Their teacher is the schools System Administrator ICT and above average interested in IT which made this system particularly interesting to him. He likes to include technology in the learning process, and has used tools such as the iPad to engage his students in subjects earlier.

10.3 Procedure

In this section I will describe how the evaluation was prepared, how it was conducted, and how data was collected.

10.3.1 Deviations from the intended use

As the duration of the evaluation was limited to a single school day, some changes were made compared to the original intended use as seen in figure 2.2. As the setup

interface has not been created, the teacher only provided me with the required information, and I set up the session on his behalf. Also there was not enough time to include the individual reflection in the evaluation, so this part was skipped. Leaving the three steps GameStartup, Play Game, and Collaborative reflection from the original intended use to be included in the evaluation.

10.3.2 Setting up the activity

Before the evaluation I was given access to the schools iPad locker, and installed the mobile application on ten of their devices. After having prepared the devices I had a meeting with the teacher that was going to participate in the evaluation to create a game session with the images and information he wanted. After deciding what images should be included in the quiz, they were printed out and hung on the walls in various locations on the 6th graders floor. It was also decided to have some teachers standing around while the students were playing to act as guides and try to help the students if they had any questions related to the material.

10.3.3 Playing the game

As mentioned above the students were given a brief explanation on how to use the application before they were given the information they needed to start the game. After the teacher had explained the rules and divided the class into groups of 2-4 students they were given the required information and sent out of the classroom two groups at the time to avoid all the groups piling up at the first image.

When the first groups had created questions for all the images they were told to go back to the classroom and take a short break before starting phase 2 of the game. After 10 minutes or so the last groups was almost finished, and the two groups who had finished first was told that they could start phase 2 of the game. The same procedure to avoid groups piling up in front of the same image was used and after a while all the groups were out of the classroom and answering the questions created by the other groups. Upon finishing phase 2 of the game, the groups were told to take a break in the classroom while waiting for the last groups to finish.

(a) Reading information. (b) Answering questions.

Figure 10.1: Image of students using the mobile application.

Because the students used more time than anticipated on searching out information to create questions, the number of images was reduced from 8 to 6 for the group of evaluators trying out the application after lunch. Other than this, the procedure for both groups was identical.

10.3.4 Conducting the collaborative reflection session

Because of the amount of time the first group of evaluators used on creating questions for the quiz, there was very little time to conduct the reflection session. As mentioned above, the number of images was reduced from 8 to 6, and this freed up enough time to conduct a proper reflection session with the second group of evaluators.

First the teacher explained to the student why they were having the reflection session, what they were supposed to learn from it, and that the winner of the quiz would be announced at the end of the session. Since this evaluation was conducted during a single day and the students have not been able to do the homework(individual reflection), the teacher goes straight to the first image and starts analyzing the different questions and the answers the students have provided. He makes some comments on the quality of the questions, and also explains why some of the answers are wrong. He does this for all the images, pointing out issues as unreliable sources, differences between when a book was created and when it was published, etc. The students also make comments on questions they believe to be wrong or hard to understand, and the group that created the question have to argue why it is correct or wrong.

After having discussed all the questions the teacher brings up the scores and an-

nounces the winner as well as 2nd and 3rd place. He then proceeds with telling them what the highest possible score was, and tells them to think of what they could have done to get closer to this score. A few hand pops up and suggestions starts coming from the students. After hearing what the students have to say, the teacher sums the suggestions up and makes a list of what the students can improve for later activities.

10.3.5 Answering questionnaire

After finishing the reflection session, both students and the teacher was asked to fill in the questionnaire found in appendix D. The questionnaire given to each student consisted of 30 questions where 13 questions were connected to the game (1.1 - 1.13), 13 connected to the reflection session (2.1 - 2.13), and 4 questions about the system in general(3.1 - 3-4). The questionnaire given to the teacher consisted of 15 questions regarding the game, 11 connected to the reflection session, 5 questions regarding the system as a whole, and also 4 fields requiring a textual answer from the teacher.

The statements in the student questionnaire concerns different aspects of the system that this thesis is trying to assess:

- Engagement and motivation - Statements: 1.1 1.6 1.7 1.8 1.9 2.1 2.8 3.3 3.4. These statements were meant to determine whether the students were engaged throughout the evaluation, and to see if certain elements of the system motivated them to do their best.

  1.1: I enjoyed playing the game.
  1.6: I contributed to solving the tasks provided through the system.
  1.7: The game was fun.
  1.8: I did my best in order to win the game.
  1.9: The competitive aspect of the system motivated me to perform better.
  2.1: I enjoyed partaking in the reflection session.

- MAR technology - Statements: 1.2 1.3 1.4 1.5.
  These statements were meant to determine whether or not the MAR technology had a positive effect on the students engagement.

  1.2: AR content did not divert my attention away from the paintings.
  1.3: AR was a nice way to present information.
  1.4: The use of AR made the game more fun and interesting.
  1.5: The use of AR made me more engaged in the game.

- Learning - Statements: 1.10 2.2 2.3 2.4 2.13 3.1 3.2.
  These statements were meant to determine whether the students feel the system helps them improve their knowledge on the given subject and also their ability to learn. Even though the learning outcome can not be measured during a one day evaluation, their thoughts should give an indication on whether it has a positive effect compared to traditional tutoring.

  1.10: I learnt a lot while playing the game.
  2.2: I learnt a lot during the reflection session.
  2.3: The reflection session made me realize what I could do better next time I use the system.
  2.4: Because of what I learned during this reflection session I will perform better the next time I partake in a similar activity.
  2.13: By reflecting on the visit I realized how I can learn material more efficiently.
  3.1: I learnt more using the system, than i normally do in class.
  3.2: I know more about the subject now than before using the system.

- Information gathering - Statements: 1.11 1.12.
  These statements were included to see if the students used external sources or the information provided by the teacher when they created questions. This can also be used to determine the students engagement by seeing how much effort they put into creating hard questions.

  1.11: I used the information provided by the teacher to create questions.
  1.12: I searched out information using other sources to make it hard for other groups to answer.

- Information presentation - Statements: 2.5 2.6 2.7 2.9 2.12.
  These statements were meant to determine whether the information on the reflection website was presented in a way that provided the students with material to reflect upon.

  2.5: I found the material in the reflection session interesting.
  2.6: All the data I would like to see after playing was available on the website.
  2.7: The score was presented in a good and orderly way.
  2.9: The website made it easier to remember my experience from the museum.
  2.12: Overall, information was presented in a good way.

- Usability - Statements: 1.13 2.10.

these statements were meant to determine whether the students found the system easy to use or not.

1.13: I found the mobile app easy to use.
2.10: The website was easy to use/understand.

The questionnaire answered by the teacher was not the same one that was answered by the students. The teacher questionnaire included statements concerning:

- Student engagement and motivation - Statements: 1.4 1.8 1.9 2.7 2.8 3.4.

  1.4: The students seemed to enjoy playing the game.
  1.8: I think that playing in groups made the experience more fun for the students.
  1.9: I think the student put a lot of effort in trying to win the game.
  2.7: The students seemed eager to partake in the reflection session.
  2.8: Not announcing the scores until the end of the session helped motivate students to pay attention.
  3.4: I think the students seemed more eager about the subject when using the system (compared to not using the system).

- MAR technology - Statements: 1.11 1.12 1.13.

  1.11: Using image recognition to identify images seemed like a good solution.
  1.12: Using MAR to present information to the students seemed to make them more engaged in the activity.
  1.13: I was able to present all the information I wanted the students to see via the AR content.

- Learning - Statements: 1.7 2.4 2.6 2.11 3.1 3.2.

  1.7: I think that creating the questions helped students learn something new about the different items.
  2.4: Discussing questions increased the learning outcome for the students.
  2.6: The reflection session helped the students identify how they could improve their performance for later activities.
  2.11: Having the students write down what they can do better the next time they use the system will help them become better learners.
  3.1: The system made it easier to educate students on this topic.
  3.2: The system helped me map the academical level of my students.

- Usability - Statements: 1.1 1.3 1.5 1.15 2.1.

  1.1: It was easy to relate the information from the curriculum to images.
  1.3: I thought the game was easy to use for the students.

1.5: It was easy to make the students understand how to play the game.
1.15: It was easy to monitor the students through the website.
2.1: I thought the website was easy to use during the reflection session.

- Data collection/presentation - Statements: 1.10 1.14 2.2 2.3 2.10.

  1.10: The data collected with the application helped me guide the students through the reflection session.
  1.14: It was helpful to be able to monitor the answers and questions submitted while the student while they were playing.
  2.2: I think the website provided sufficient and relevant content for reflection.
  2.3: It was easy to start discussions among the students based on the information provided by the website.
  2.10: The information available on the website was presented in a good way.

It also included some statements regarding other aspects of the system, as well as a few questions allowing the teacher to give a textual answer.

All the statements in the questionnaire was given a rating from 1-5. 1 indicating that the person strongly disagrees with the statement, and 5 indicating that the person strongly agrees with the statement.

10.4 Results

In this section I will present the results of the user evaluation. Since the students and teacher have different roles when using the system, I will present the data gathered from the two separately. First the results from the student questionnaire will be presented together with the notes I took during the evaluation, and then the results from the teacher questionnaire followed by a brief summary of the comments he made about the system.

10.4.1 Students

The data covering the mobile application was collected by all 51 participants, but since the first group of evaluators did not have time to conduct a proper reflection session I will only use the data from the second group of evaluators (25 students) when presenting the data connected to the reflection session. The overall results of the user evaluation can be seen in figure 10.2. These results were calculated by taking the average score of all the students combined, since the first group of evaluators did not conduct a proper reflection session I have only included the

answers they provided regarding the game (statement 1.1 - 1.13) when calculating the overall results.

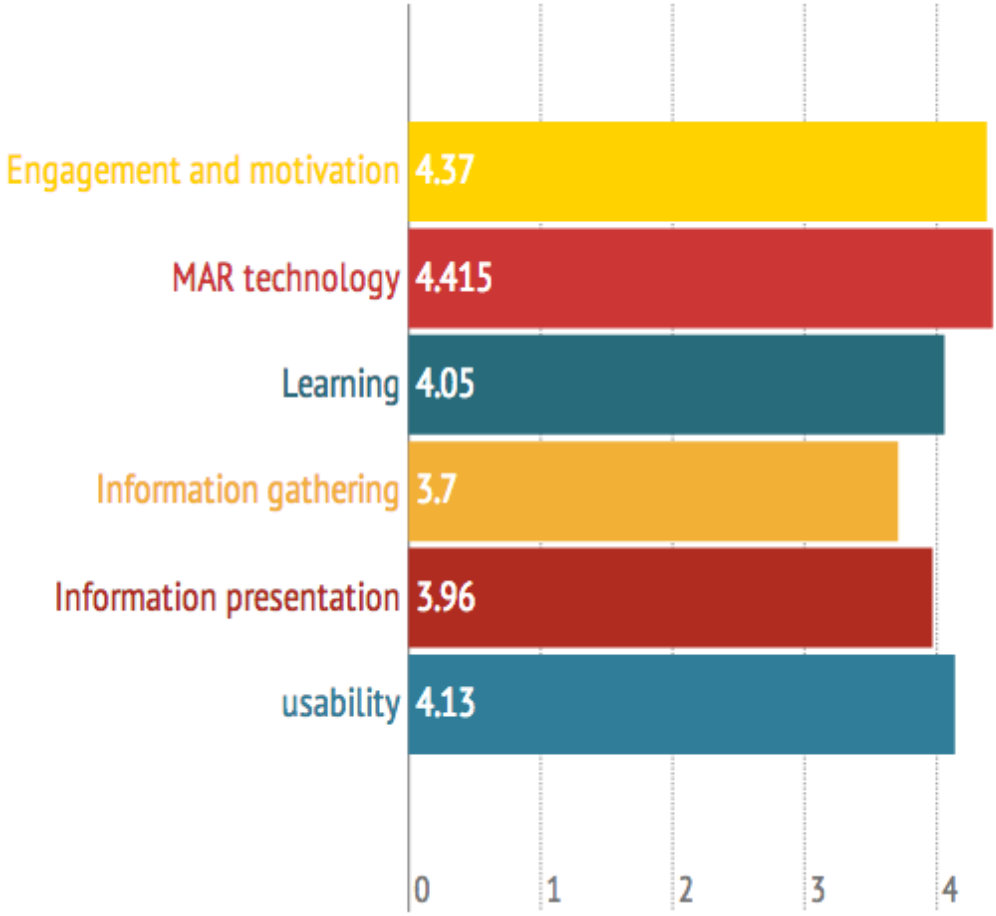


Figure 10.2: Overall results of user evaluation

Engagement and motivation

When observing the students throughout the exercise the overall perception was that almost all students were really engaged while using the system. Even though the exercise went beyond their recess most of the students did not seem to care since they were too eager to find the next image and create or answer questions connected to it. The competitive aspect of the game also became very clear when groups got to close to each other. Whispering and making sure the others groups could not see their answers showed a certain level of engagement in the activity.

"Go away, don't look at our question!"

During the reflection session the students had a lot of comments regarding the questions created by themselves as well as questions created by other groups. As discussion broke out they all seemed eager to contribute with their opinion or to explain themselves. An example was a group who had created a question about when a book had been released, and had mixed the dates of the original release and the Norwegian release.

The idea of keeping the scores hidden until the end of the reflection session seemed to keep the students engaged in discussions as they had been informed that the scores would not be revealed before the collected data had been reflected upon. But the results regarding engagement and motivation from the questionnaire shown in figure 10.3 question 2.8 showed that there was disagreement regarding this statement.

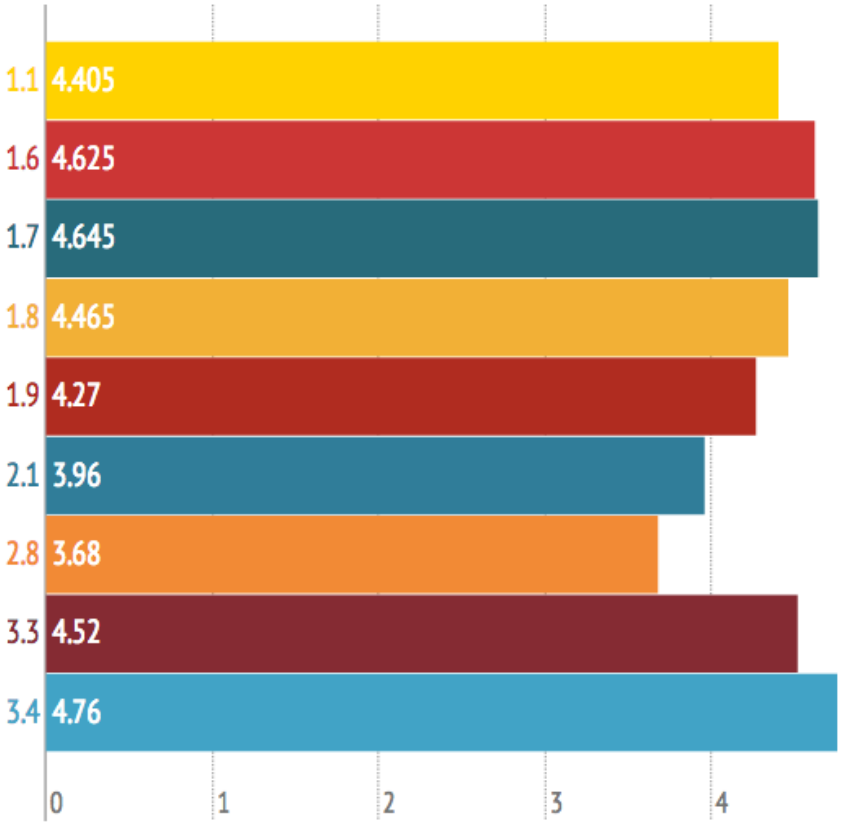


Figure 10.3: Average score on engagement and motivation statements.

The results from the questionnaire reveals that the students motivation and engagement level throughout the exercise is quite high, but a small decline can be seen in the statements connected to the reflection session (2.1 and 2.8).

MAR Technology

The MAR technology included in the mobile app seemed to have a very positive effect on the students attitude towards the exercise. As each group scanned their first image they all seemed pretty amazed, and spent time reading through the material and looking at the images before continuing with creating questions. Some groups found it difficult for all the group members to read the information simultaneously, but solved this by sending the iPad around if someone wanted a better look. I observed that many of the groups memorized the information provided by the teacher in order to create questions that could not be answered by simply reading the provided information. Another issue that surfaced was that the students had trouble with getting far enough away from the image to view all the AR content at the same time. This was because some of the hallways the images had been hung were quite narrow and made it impossible for them to move more than 1-2 meters away from the image.

> *"Those floating images are awesome!"*

For some groups the image recognition used to identify the images distracted them. Instead of finding the image they were supposed to scan, they spent time trying to scan other objects or persons in the group. This was not a big issue, as they quickly found out that it could only recognize the images that the teacher had picked out.

The results from the questionnaire showed that the MAR used in the mobile application had positive effect on their experience in relation to fun, engagement, and ways to present information. The effort to not divert focus away from the target image seemed to be somewhat a success, even though statement 1.2 in figure 10.4 got the lowest score AR statements.

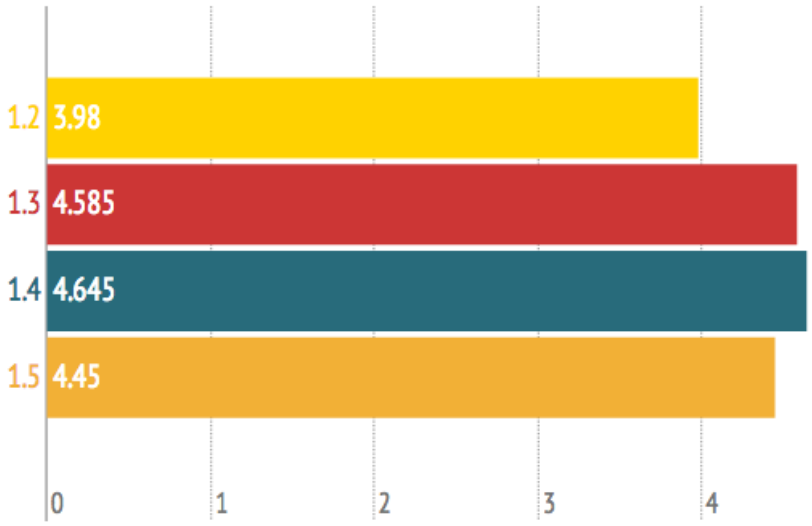


Figure 10.4: Average score on statements regarding the augmented reality in the mobile application.

Learning

The learning outcome of using the system is hard to say much about with only one evaluation over such a short period of time. The results from the questionnaire and comments made during the reflection session indicate that the students themselves think they are learning. This fact at least has the potential to motivate the students to learn while using the system.

> *"The system was fun to use, therefore we learn more."*

The fact that the student actually tried to memorize the information provided by the teacher in order to search out information that was not there shows that they made an effort to remember this information. This is not always the case if the teacher is simply presenting the same information in front of the class with nothing else than expanded knowledge on a subject as a goal or motivator.

By looking at the data collected with the questionnaire we can see that the students think they learn more from the game than the reflection session, even though the majority also thinks that they have learned a lot while reflecting. The reflection session also helped them identify what they could do better the next time they use the system.

Without conducting an evaluation over a longer period of time the data can not be used to assess the learning outcome.

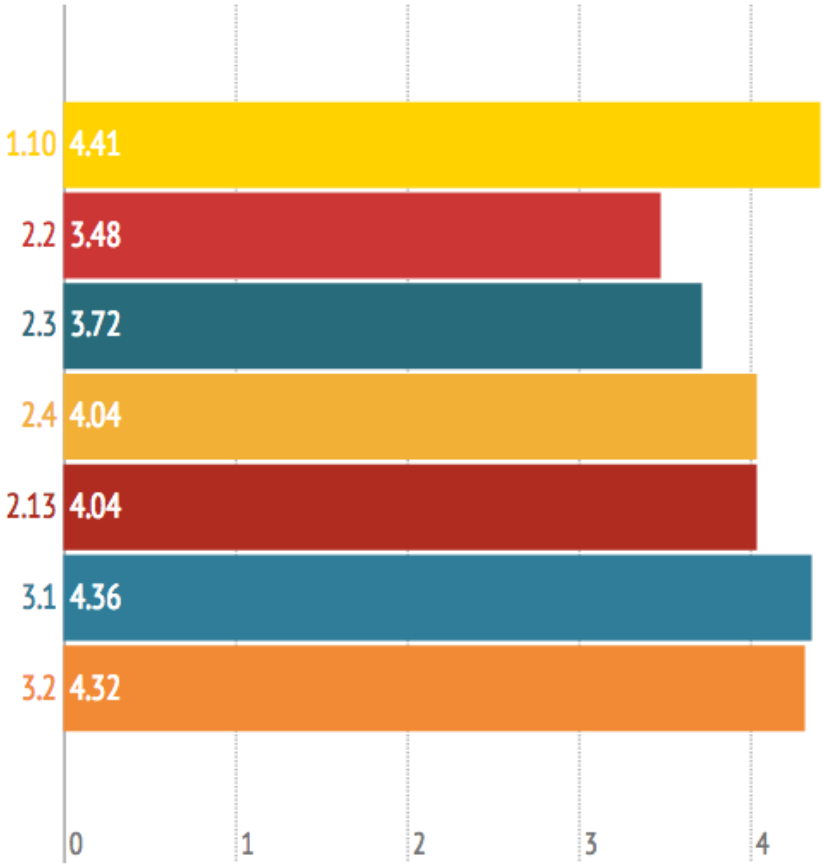


Figure 10.5: Average score on learning statements.

Information Gathering

As mentioned earlier I observed that most of the students read through the information provided by the teacher, but not to use it while creating questions. Instead they read the information to be able to create questions where the answer could not be found by simply reading the provided text.

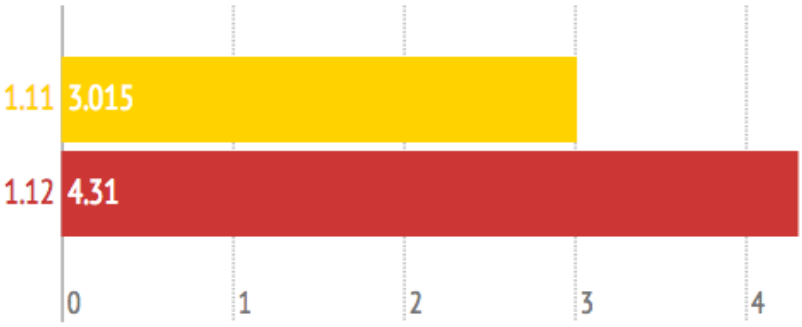


Figure 10.6: Average score on information gathering statements.

The observations I made were confirmed when looking at the results from the questionnaire. Figure 10.6 statement 1.12 shows that most groups used external sources to find their information instead of using the information provided by the teacher (statement 1.11). During the reflection session one could also see a connection between who had only used the information provided by teacher, and which groups got lower scores. These groups seemed to agree that they would have to use more time on searching out information the next time they were going to play.

Information Presentation

The students seemed to be satisfied with the way all the collected data was presented. Nobody seemed to have issues with seeing the information presented in front of them on the shared screen and seemed happy about the way it was presented.

The questionnaire revealed that some students were not satisfied with the amount of data available to them through the reflection website. No suggestions on what kind of data they would like to see surfaced while I was there or got mentioned in the comments section of the questionnaire, so some additional work would need to be done to uncover what other kind of data could be included.

Using visual graphics to present the score to the students was a very popular solution. Each group easily found their own score, and quickly saw how they had done compared to the other groups.

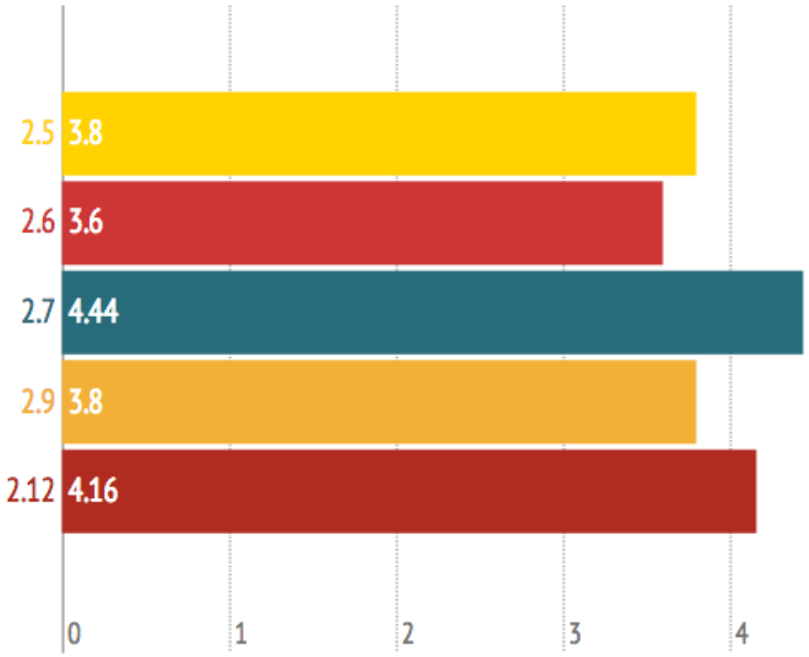


Figure 10.7: Average score on information presentation statements.

Usability

Looking at the results from the questionnaire in figure 10.8, the majority of students found the system easy to use. Before starting the evaluation I told the class that I would only help them with technical issues, and that if there was anything not working they should come to me for help. This way I would be able note down the errors as well as helping the students carry on with their exercise.

As the students were playing many groups came to me to say that no new image appeared when they pressed continue to find the next image. This issue turned out to be caused by the schools wireless routers which did not have sufficient capacity to handle such a large amount of devices at the same time, thereby causing an increase of the time it took to load the images from the server. As a result the students had to be patient and wait around a minute or so for the hint image and instructions to load before they could continue to the next image.

Even though the students in 6th grade had no problem with the language in the system (English), they commented that having the opportunity to select the language they wanted would be a nice feature. And that if this feature was implemented it could be used by the students in lower grades as well.

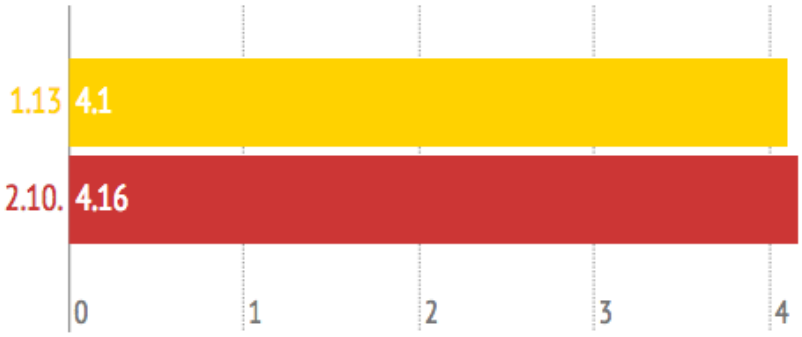


Figure 10.8: Average score on information usability statements.

Comparing the two groups

Since only the second groups of evaluators had time for a proper reflection session I will use this to compare how the students perception of the system were when conducting the reflection session opposed to just playing the game. In figure 10.9 the average score from the two groups for statement 3.3 and 3.4 can be seen.

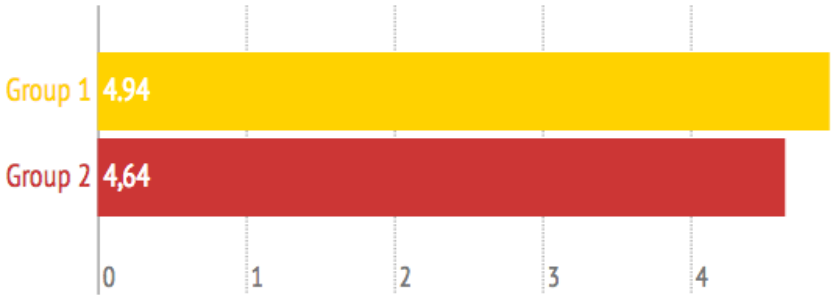


Figure 10.9: The two groups overall perception of the system.

Here the average score of group 1 is based only on the mobile game since they did not have time to conduct the reflection session. The average score of group 2 is based don both game and reflection session. A slight decrease can be seen, but this might also be caused by group 2 being the last group to test the system. As the teacher said: "The closer we get to the end of the day, the lower their engagement gets". Not taking into consideration that group two evaluated the system later in the day leaves us with results saying that the reflection session had a slightly negative influence on the students overall experience.

Evaluating the reflection session with only one group also opens up the opportunity to see if it had an effect on the students own thought regarding the learning outcome of using the system. Figure 10.10 shows the average score on statement 3.1 and 3.2 of both groups, and we can see a slight decrease in group 2. This might also be caused by the fact that group 2 evaluated the system closer to the end of the day, but further research is needed to determine whether the reflection session has an effect on the learning outcome or not.

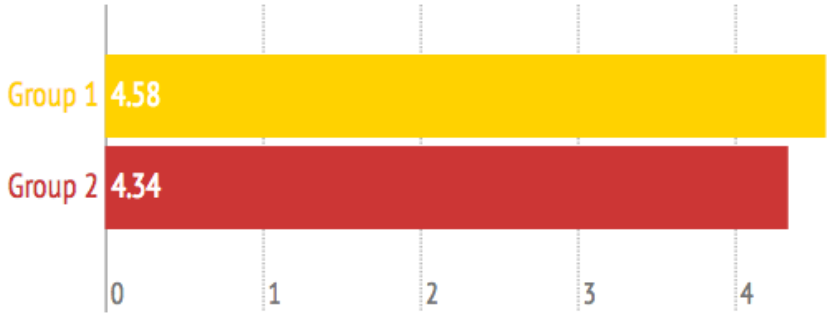


Figure 10.10: The two groups overall thought on the learning outcome of the system.

10.4.2 Teacher

Data for the teacher evaluation was collected through a questionnaire that was given to him right after he had conducted the reflection session and a sit-down with him where I asked for his opinions and thoughts surrounding the system. Bellow I will try to sum up his answers from the questionnaire, and present the information I got from him during the sit-down. Figure 10.11 sums up the scores given to different aspects of the game (higher = better).

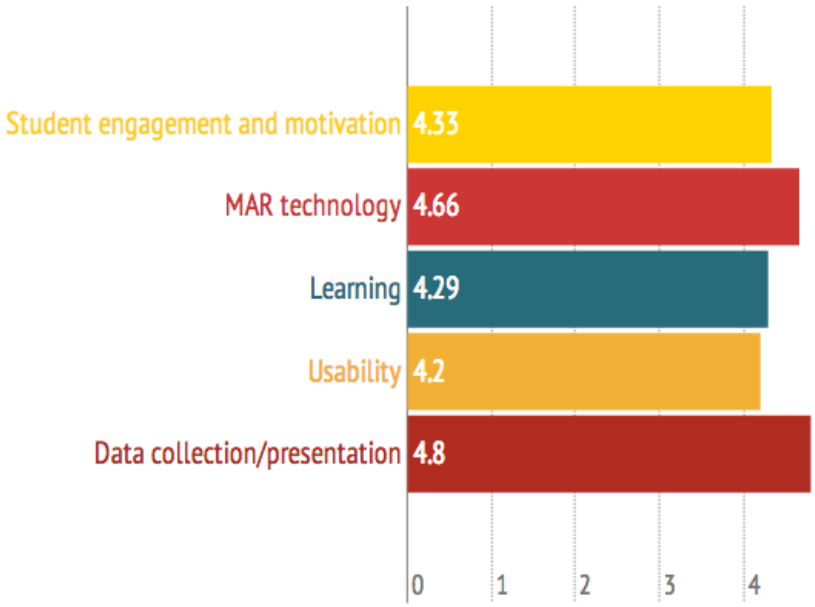


Figure 10.11: Overall results from the teacher questionnaire.

Student engagement and motivation

When the teacher is trying to assess the level of engagement and motivation in his students, he has to compare it with normal tutoring and earlier activities he has seen the students participate in. Based on these criteria he thought the students seemed to be having a lot of fun while playing the game, and thinks that allowing the students to play in groups made it even more fun for them. He also thought that the students looked like they put a lot of effort into winning the game.

The engagement level of his students during the reflection session he thought was a bit low, but commented that this was probably because it was near the end of the school day, and the students were tired. Unlike his students, the teacher thought that keeping the scores hidden until the very end of the reflection session motivated them to pay attention. At last he thought his students seemed more eager about the subject when they were using the system, compared to what they normally are.

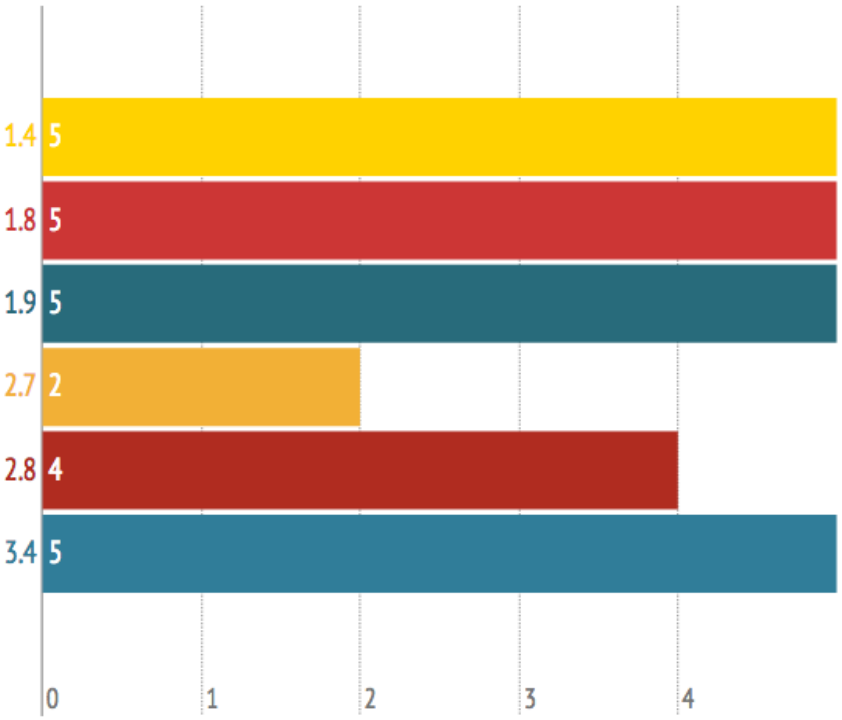


Figure 10.12: The teachers perception of his students engagement and motivation.

During the sit-down he also mentioned that the students loved to use the iPads in school, and that this alone also helps them get engaged in whatever activity they are doing.

MAR technology

The teacher thought the combination of image recognition and MAR was a good solution, and that image recognition was a nice and easy way for the students to identify images. He also agreed that this way of presenting information to the students made them more engaged in the activity at hand. When creating the session he discovered that the information he had prepared for some of the target images was to much, and therefore had to shorten it down. He was able to include all the information he wanted, but thought the AR elements could be more flexible in case more there was more information he wanted to include.

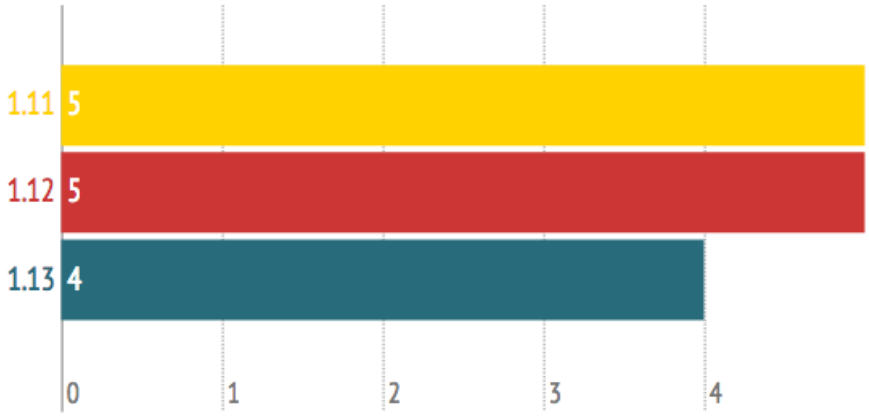


Figure 10.13: The teachers evaluation of the MAR technology used in the mobile application.

Overall he thought the MAR technology was a really good way of getting the students engaged in the activity. The only thing he would like to see that was not included in the system as of today was the ability to recognize 3D-objects, saying that this would enable him to use the system more frequently.

Learning

The results presented in this section derive from a single day evaluation and can not be used to determine the academical gain of using the system. However, the results give an overview of what aspects of the system the teacher believes to have a positive effect on the learning outcome. Assessing the academical gain of using this system is not part of my thesis, but the data in this section can be of help when further developing the system.

The teacher agreed that allowing the students to create questions helped them learn something new about the subject, and that discussing these questions in class helped to improve the learning outcome. He was uncertain if the reflection session had helped them identify how they could improve their performance (see statement 2.6 in figure 10.14), but looking at my notes from the evaluation I could see that specific measures was suggested during the reflection session. He agreed that writing this down for a later activity would help the students become better learners. The system's ability to help him map his students academical level he was not sure of, but thought it made it easier to educate his students on the given topic, and that it has the potential to increase students learning capabilities.

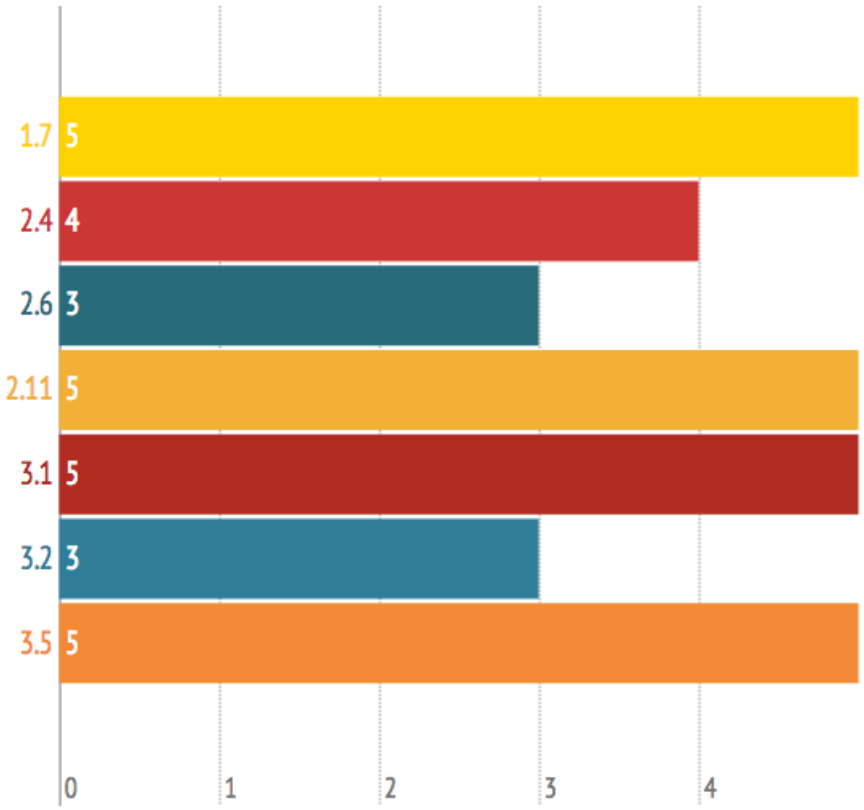


Figure 10.14: The teachers evaluation of the systems learning capabilities.

He was very pleased with the pedagogical approach used to design the system, and pointed out that many of the applications available to them lacks the properties found in this system.

Usability

Being skeptical to how he was going to relate information to images at first, the teacher had no problems with finding images through which he could present the information. He found it was easy to make the students understand how to play the game, and had no problems monitoring them while they were playing using the website. Using the same website he experienced no issues and navigated with ease during the reflection session as well.

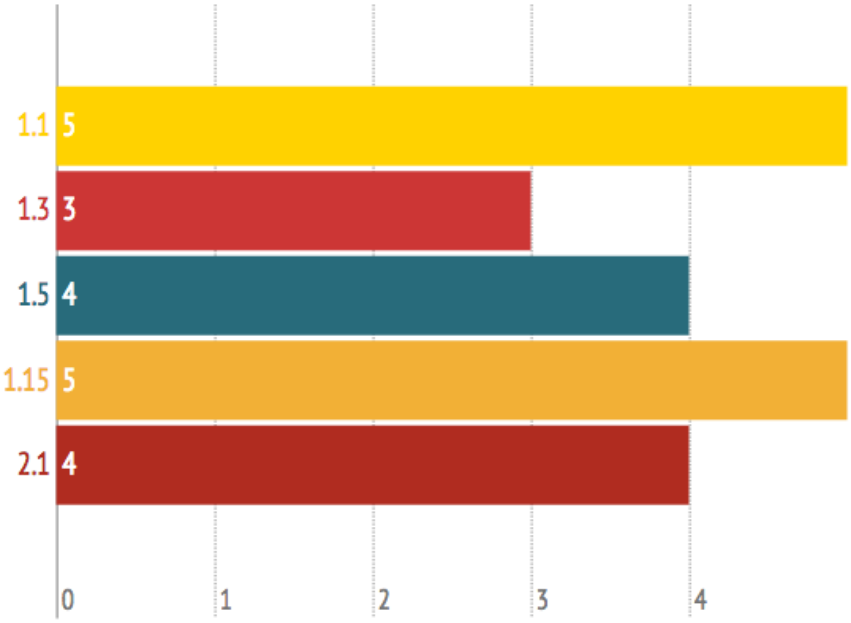


Figure 10.15: The teachers evaluation of the usability of the system.

Before using the system I had given the teacher some brief instructions on how to use it. He later commented that without these instructions he would not have been able to use the system as easily as he did.

Data collection/presentation

The teacher found it helpful to be able to monitor his students though the website while they were creating questions. He also said that information he needed while monitoring the students did not look very appealing, but provided him with what he needed. During the reflection session he thought the website provided him and his students with sufficient and relevant data for reflection, and that it was fairly easy to start discussion among the students based on the available data. He was pleased with the way information was presented, but also said that a finished version of the system might benefit from looking a bit more polished.

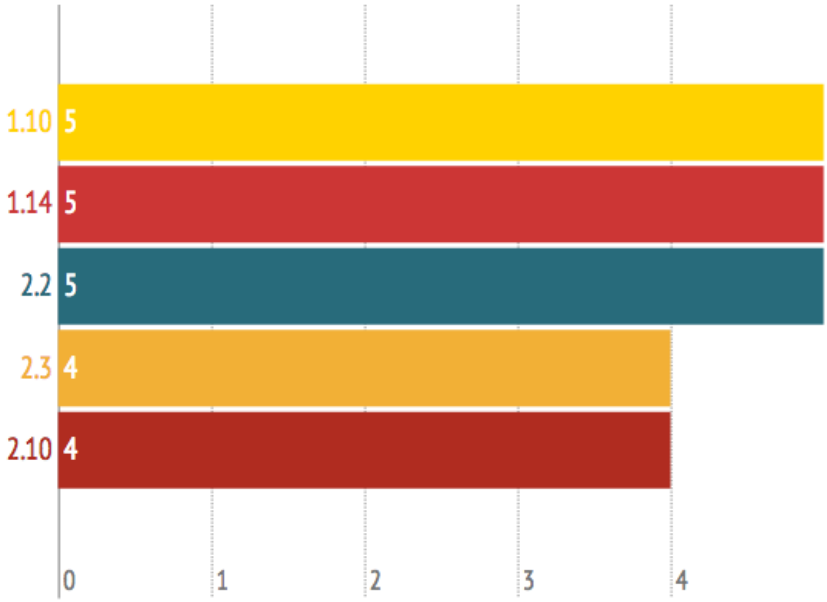


Figure 10.16: The teachers evaluation of the data that was collected and how it was presented.

Further comments

At last he said he was very pleased with the systems flexibility that allowed him to customize so much of the content in the application himself, and that the user interface could use a touch up to make it look nicer. Further he said that he would definitely recommend the system (when fully developed) to his colleagues, and the school would be more than glad to participate in further testing of the system.

Chapter 11

Discussion

In this chapter I will discuss the results and experiences from the usability testing, the expert evaluation, and the user evaluation. This will be discussed in regard to the research questions I am trying to find the answer to with the musARum system. I start with discussing usability issues and the changes I made compared to the earlier system before I discuss each research question separately and give a summary of the discussion at the end.

11.1 Usability and Technical Issues

Usability is not part of my research questions, but I have chosen to include it in the discussion because it effects the users experience while using the system, and can therefore be a factor when it comes to the engagement level of the users.

11.1.1 Technical issues

During the user evaluation no major issues with the system itself was discovered, but an issue with the equipment on site caused some trouble. Since they had not used the schools wireless network with this many devices at the same time before, they were not aware that the routers they had installed could not handle so many devices at the same time. Because of this many groups experienced long loading times, and got confused since they did not receive instructions on what to do next. The issue with the school routers is something that can only be fixed by the school itself, but changes can be made to the mobile application so that the users knows what is going on. Presenting the users with an informative loading

screen while downloading data could be a way to avoid confusion when dealing with slow connections.

11.1.2 Usability

Even though the users seemed to be satisfied with the usability of the system a few suggestions on how to improve it surfaced during the evaluation. As mentioned above, ways to handle issues with slow connections should be implemented so that the users know why nothing is showing up on their device and what they are waiting for. The evaluators knew that this was a prototype, but suggested that giving the application a more polished look (including loading screens) would make it easier for them to use it. Also, allowing the user to choose the language of the application would enable even younger students to use it.

11.2 Changes from earlier system

As the musARum system build on some of the ideas in the MagMAR system presented in chapter 2, I will here discuss how the most significant differences from the earlier system have worked out.

11.2.1 Image recognition

The main reason for using image recognition instead of QR-codes (used in MagMAR) was to avoid the user focusing on the marker instead of the target image. Looking at the results in figure 10.4 where statement 1.2 said that "AR content did not divert my attention away from the paintings" we see that the majority of students did not lose focus from the image. Even though some images (those with very low detail) can be hard for the application to recognize, none of the images used in the evaluation had this issue, and students were able to identify images almost instantly by just holding the camera up in front of the target image. Even though the evaluation conducted in this thesis did not encounter any issues with the image recognition it might become as issue if the target images does not have a lot of detail (e.g. some modern art images can be very minimalistic).

11.2.2 Group size

In MagMAR the user were divided into two groups, and the results from the questionnaire were split when asked if the other team members were helpful. This suggests that some users had to do most of the work while the rest was just along for the ride. Therefore the suggested group size when using musARum was changed to 2-4 persons. The results in figure 10.3 statement 1.6 shows that almost all the participants thought they contributed to solving the tasks they were given while using the system. This is of course the participants own opinion, but as I observed them during the evaluation there seemed to be good communication within most of the groups and all members seemed to be contributing. A possible issue with having smaller groups is that it requires more devices and therefore requires more from the users or the school.

11.2.3 The process

When changing the group sizes, the process of using the system also had to be changed. The new process allowed all the students to visit all images, and it was decided that the teacher defines the order in which the images are visited. Having the teacher create a route for the students to follow proved to cause more problems that it solved. To avoid all the groups piling up at the first image, they had to be sent out one by one while the others were waiting in the classroom. Because of this the evaluation took much longer than needed. In some settings in might be beneficial to let the teacher decide the route which the students should follow, but this feature should be optional in later versions of the game.

11.2.4 Portability

Instead of developing a native application for just one operating system, musARum supports all the major mobile platforms. This enables users to use the application with the device(s) they have available. Having the opportunity to run the application in iOS as well as android proved to be well worth it since the school at which the evaluation was conducted only had iPads. Had the application only been for android devices I would have had to provide the school with the tablets myself. I learned that most elementary schools in Norway does not allow the students to use their own devices during school time, so it is important that the application can be installed on whatever devices the school can provide.

11.3 RQ1

Does the use of state of the art MAR technology engage young learners?

With the usability study and expert evaluation I was not able to determine whether the MAR technology had an influence on young students engagement levels due to the fact that the participants was not young student. However, it was useful to see their reaction when using it for the first time, and also get feedback on how it was implemented. The user evaluation showed me through both the answers given on the questionnaire and the observations I made during the evaluation that the MAR technology used it the mobile application had a positive effect on the students engagement level, and that they also thought this themselves. It was interesting to see how the mood in the classroom changed when they were told/showed what they would be doing instead of the regular lectures. The fact that they were going to use iPads seemed to raise their engagements level by itself, but when they were showed how to identify images and interact with the information connected to them their excitement towards using the system became really evident.

During the evaluation one could see that in the first phase of the game the students seemed very eager every time they had to scan a new image and was exited to view the information connected to it. During phase 2 their excitement about the augmented objects dropped a little as they already knew what information would appear. Even though they still used some of the information, their focus had now shifted towards answering the questions and the information presented through MAR was only viewed when necessary.

11.4 RQ2

How can digital data collected during an activity be used in a collaborative post-game reflection session?

The expert who evaluated the system stated that all the information that was available to students during the activity should also be available during the reflection session. This information included the textual information, augmented images, and the target image itself. These were all included in the reflection session taking place during the user evaluation, and was presented together with the questions and answers provided by the students. It turned out to be a good way for the students to identify what target image they were discussing, but was rarely used for anything else. There were not that many of the questions created by the

students that were directly connected with the augmented images, so if this was not the case they might have been of more use.

Some of the participants in the usability study commented on the size of text and images on the reflection website, saying that it should have bigger images/text if it was going to be read from a distance. An issue I had not given any thought to at the time, but an important one never the less. Keeping in mind that most projectors today run with a fairly low resolution, the website was modified, and students were able to see the information presented on the collaborative screen.

The data collected through the mobile application proved to be sufficient (according to the teacher) to be able to start discussions among the students. As the data was presented, extra time was spent on questions proving hard to search out the information for, confusing answer-alternatives, and questions based on unreliable sources. The groups were quick to contribute to the discussion as soon as they spotted a question they had trouble answering, or someone made a comment about a question they had created. Seeing the answers from all the other groups seemed to lower the threshold for joining the debate because they could see that other groups had struggled with the same question as well.

Questions and answers from the quiz were presented to the students as plain text using a table on the website. Not very exciting to look at, but easy to navigate and understand. Looking at the results from the evaluation it is clear that they liked the graphical presentation of data used with the scores. Finding ways to present the rest of the data in a similar way could be interesting as it might help with making the students more engaged in the reflection session.

In addition to being used as background for discussion, the data also proved valuable to identify what could be done better the next time a similar activity would take place. This being the first time they had ever used the system they were able to see what questions the other groups struggled answering, where they searched for information, etc., and can now use this knowledge to get an advantage the next time. Looking at how the user generated content evolves from one session to another could be both interesting and educational for teacher and students.

11.5 RQ3

How can a post-game reflection session help students improve their learning capabilities?

The teacher partaking in the user evaluation was unsure of whether the students had been able to identify how they could improve their performance for the next activity, but agreed that writing it down would help them to become better learners. The expert evaluator suggested implementing functionality into the system that would enable the students to log in and save their notes so they could read them before doing similar activities. Even though I observed some suggestions being made on how they could do better next time, actually having the students write this down could help make it clearer exactly what they should do different. Had this been a required step in the process of the reflection session it might have gotten prioritized higher, and more specific measures could have been identified.

The results from the questionnaire showed that the students did not find it very useful to hear how other group had acquired information to create questions, but became very engaged when the teacher commented on the different sources they had used, and why they were good or bad. Even though the information on how they gathered information was believed to not be as useful, the resulting discussion helped them understand how one can determine whether an online source is reliable or not.

Chapter 12

Conclusion

This chapter reviews the results and contributions of the work presented in this thesis as well as a self evaluation and a section presenting the future work for improving this project.

12.1 Summary

In this thesis I have investigated how to design a website that supports reflection in a post-activity reflection session, and further developed the mobile application created to investigate how MAR can effect young students engagement in an educational setting. An analysis of related games/systems and theory on reflective learning were used as a basis when designing the website. The whole system consisting of the mobile application and the reflection website has gone through a usability test and has been evaluated by an expert as well as a group of students and their teacher.

The evaluated system consists of a multi-platform mobile application and a website for supporting the reflection session. The mobile application utilizes image recognition and MAR technology to engage users in a quiz where the content is created by the users themselves. The website presents the user with both textual and graphical data generated from the quiz to enable them to reflect on their experience.

Results from the evaluations shows that MAR can be used to increase the engagement level of students, and that the system has the potential to improve students learning capabilities. To further support the reflective learning process, the system should be extended with functionality that enable its users to store notes from the

experience that can be reviewed before partaking in a similar activity at a later point in time. A tool making it easy for the teacher to set up a new activity is also needed if the system is to be used without help from a technical person. The feedback from the evaluations suggests that the system was successful in creating an engaging and educational experience for its users.

12.2 Discussinon on my own work

The primary work done in this thesis was the design and development of a multi-platform mobile application and a website which together constitute the musARum system. Developing the musARum system challenged me to learn a lot about the development of mobile applications, which I had little to no experience with before starting this project, and to further expand my knowledge on developing websites.

As my research depended on a user evaluation to take place, I would have planned this earlier and also make a backup plan if I was to do it again. Due to illness, the group of student I had originally planned to evaluate my system with had to cancel last minute, and I had to start the process of finding a new class to participate in the evaluation. Luckily I was able to get in contact with a school a few weeks before my deadline, but this unforeseen happening caused the final weeks before delivery to become very stressful. Even so, I am very pleased that I was able to conduct a user evaluation with more than 50 students, and that it was carried out with very few problems. Looking back on the work, I would also have conducted the expert evaluation before starting the development. This way changes such as the single user login could have been planned and implemented without taking to much time.

In the beginning of this project the musARum system was designed only for use in museums to look at paintings. Having spoken to the expert about the flexibility of the system, it became clear that it could be used in other areas as well. Looking at the user evaluation where paintings were switched out with images of books, I would say that the system was applied to a different part of our cultural heritage (literature) with great success.

All in all, I look back at the work I have done in this thesis with pride. It has been an interesting assignment were I have had the opportunity to work with new and interesting technology, most of which I had not used before this project. It has been challenging in terms of both design and implementation, but I have learned a lot from it. Also, being able to see the system tested with real users which seemed

to really like what I have created, left me with a big sense of satisfaction.

12.3 Future Work

In this section I will present some ideas to future work with the system that surfaced during the different evaluations that I did not have time to implement in the current version of the system.

12.3.1 Improvements to the mobile application

3D-object recognition

If the mobile application was able to recognize 3D objects as well as images it would improve the applications area of usage. The teacher partaking in the user evaluation argued that this would allow him to take the students on excursions to places like Frognerparken, Oslo, where the students could create questions connected to the different statues. This might be possible to do with the application as it sits today by adding multiple target images from different angels connected to the same information, but this has not been tested.

Google search on image press

During the usability testing a participant suggested that functionality that would allow the user to simply tap the augmented images to perform a Google search for them could be useful. I found this suggestion very interesting, and the possibility to implement it in the application should be looked into as I did not have time to do so.

Newest version of Vuforia

During the development of the mobile application in this thesis a new version of Vuforia[1] was released. The new version includes functionality that enables the camera to track objects even though they are outside of the camera view. This could make it easier for the users to view information in situations where they have to stand very close to the target image and is not able to get images together

[1] https://www.vuforia.com/

with the information into the camera view. Installing this update should be fairly easy, but I was not able to do it before conducting the user evaluation.

Informative loading screens

During the user evaluation the users experienced issues with the schools routers which caused the application to load instructions and hint images very slowly. As this had not been an issue while testing the prototype earlier, no measures had been taken to inform the user what is going on. To avoid users thinking the application has frozen, loading screens with information on what is going on should be included.

12.3.2 Improvements to the website

Storing user notes

To enable the students to review their notes from earlier activities the website should allow them to log in and save their notes after each reflection session. In addition to being a safe place for the students to store their notes, this functionality could make it easier for the teacher to dedicate time to let the students identify how to improve their performance.

Session setup interface

As of today each session is created by manually editing the database. This has to be changed before the system can be used by its intended users without any assistance.

12.3.3 Process improvements

Even though the teacher liked the idea of deciding which route the students should follow, he thought that this would not be necessary in all settings. Therefore he suggested that setting up a route for the student should be optional, and chosen by the teacher when creating the session.

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Appendix A

Usability Questionnaire

Questionnaire

Answer on a scale from 1-5 how easy it was to accomplish the task:

1. Fill in the needed information and start the game.

Very easy Very hard

2. Find the correct painting and create a question.

Very easy Very hard

3. Complete Phase 1

Very easy Very hard

4. Start Phase 2 and answer the questions

Very easy Very hard

5. Complete Phase 2

Very easy Very hard

6. Add a question connected to the quiz via the website

Very easy Very hard

7. Browse the questions created for a specific painting

Very easy Very hard

8. Find out what score you group got

Very easy Very hard

Appendix B

SUS Questionnaire

System Usability Scale

	Strongly disagree				Strongly agree
1. I think that I would like to use this system frequently	1	2	3	4	5
2. I found the system unnecessarily complex	1	2	3	4	5
3. I thought the system was easy to use	1	2	3	4	5
4. I think that I would need the support of a technical person to be able to use this system	1	2	3	4	5
5. I found the various functions in this system were well integrated	1	2	3	4	5
6. I thought there was too much inconsistency in this system	1	2	3	4	5
7. I would imagine that most people would learn to use this system very quickly	1	2	3	4	5
8. I found the system very cumbersome to use	1	2	3	4	5
9. I felt very confident using the system	1	2	3	4	5
10. I needed to learn a lot of things before I could get going with this system	1	2	3	4	5

Appendix C

Supervisor Guidelines

Supervisor guidelines for system usage.

Creating a session

The system support both textual information as well as it is able to show the students images connected to the paintings. The text selected by the teacher should contain the information believed to be most relevant for the students, and information students would otherwise learn in class. The images should have some connection to the painting itself, and work as inspiration for the students as they are creating questions. Examples:

- Images of the artist.
- Images from the same era.
- Images of other work from the same artist.
- Images connecting the painting to a specific place or time.

The painting also has to be assigned a route number. This will allow the teacher to decide which order the students will have to interact with the paintings.

In addition to preparing the game session, the teacher needs to create questions for the individual reflection session (the homework). These questions should cover the most important parts of the curriculum. Students who have read the text connected to each painting should be able to answer these questions fairly easy, and the ones who has not will have to search out the information for themselves.

Preparing the class

Before playing the game it is important that the teacher informs his/her students how the game works, and why they are playing it.

The rules are as follows:

- Each group consists of 2-4 students.
- Each group has to create at least one question on each painting.
- Each group has to answer at least one question on each painting. The more correct answer, the higher score they will obtain.
- Questions has to be connected to the painting, deviations will be pointed out in class.
- There are no restrictions on how students gather information. Allowed to use smartphones, ask museum guides, etc.

The teacher should also explain what will happen the following day (reflection session), and that the goal of the exercise is to increase their learning capabilities in addition to increased knowledge on the subject.

Playing the game

While students are playing, the teacher can monitor their contributions in real time, and step in if some groups seem to be having trouble with the task.
Monitoring is done with the reflection website. By clicking at the different paintings, the teacher will be able to view the questions created by the groups, and the answers given to each question.

Giving homeowrk

Before ending the exercise, the teacher has to give the students their homework, and explain how they do it. Students need to be provided with a link to the website, sent by e-mail or written down by hand. It is also important to inform them that all questions submitted through the website is anonymous, and at what time the collaborative reflection session will take place.
NB! important that students provide the correct session code to see the correct questions.

Homework:

1. Answer all the questions created by the teacher.
2. (answer reflection triggering questions to evaluate your performance. Answers are not submitted, only to make the student reflect on the visit.)
3. Post any questions you might have regarding the visit.

Conducting the reflection session

The teacher should gather the whole class in front of a shared screen (projector, big screen TV etc) with the musARum webpage open. The session should start with the teacher going through and answering the questions students have submitted as homework. If many students have submitted similar questions regarding the same issue, these should be prioritized. Students are free to comment and ask further questions, but this part of the session in mainly to eliminate any misunderstandings or educate the students on parts of the visit they found interesting.

After this, the teacher should start going through the paintings one by one. At each painting all questions and answers should be reviewed, and the teacher should guide the class into discussions. Examples of discussion themes are:

- Why is this a good/bad question?
- How could this question have been formulated in a better way?
- Why is this question relevant/irrelevant?
- What made this particular question so hard to answer?

On questions where the groups have used other sources than the information provided by the teacher for creating a question, they should explain how/where they found it, and why they believe this source to be trustworthy.

When all the data has been reviewed, the teacher should open the scoring page and reveal the winner(s).

Before ending the session, all students should note down things they have learned from this experience that they believe can help them perform better next time they participate in a similar activity. Examples:

- Be more sceptical to online sources.
- Discuss questions with the others in the group before submitting an answer.
- Create question based on information that is hard to find with a quick online search.
- Read questions thoroughly before answering them.

Reviewing notes before next activity

Before partaking in a new activity it is important that students review their notes from earlier activities to see what they learned, and what they can do different this time.

Appendix D

User Evaluation Questionnaires

Teacher

Game

	Strongly disagree 1	2	3	4	Strongly Agree 5
1.1 It was easy to relate the information from the curriculum to images.	☐	☐	☐	☐	☐
1.2 It was nice to be able to decide the route which students should follow.	☐	☐	☐	☐	☐
1.3 I thought the game was easy to use for the students	☐	☐	☐	☐	☐
1.4 The students seemed to enjoy playing the game	☐	☐	☐	☐	☐
1.5 It was easy to make the students understand how to play the game	☐	☐	☐	☐	☐
1.6 The game distracted the students .	☐	☐	☐	☐	☐
1.7 I think that creating the questions helped students learn something new about the different items.	☐	☐	☐	☐	☐
1.8 I think that playing in groups made the experience more fun for the students.	☐	☐	☐	☐	☐
1.9 I think the student put a lot of effort in trying to win the game.	☐	☐	☐	☐	☐
1.10 The data collected with the application helped me guide the students through the reflection session	☐	☐	☐	☐	☐
1.11 Using image recognition to identify images seemed like a good solution.	☐	☐	☐	☐	☐

1.12 Using MAR to present information to the students seemed to make them more engaged in the activity	☐	☐	☐	☐	☐
1.13 I was able to present all the information I wanted the students to see via the AR content	☐	☐	☐	☐	☐
1.14 It was helpful to be able to monitor the answers and questions submitted while the student while they were playing.	☐	☐	☐	☐	☐
1.15 It was easy to monitor the students through the website	☐	☐	☐	☐	☐

Reflection session

	Strongly disagree 1	2	3	4	Strongly Agree 5
2.1 I thought the website was easy to use during the reflection session	☐	☐	☐	☐	☐
2.2 I think the website provided sufficient and relevant content for reflection	☐	☐	☐	☐	☐
2.3 It was easy to start discussions among the students based on the information provided by the website.	☐	☐	☐	☐	☐
2.4 Discussing questions increased the learning outcome for the students.	☐	☐	☐	☐	☐
2.5 The ability to ask anonymous questions resulted in more questions than usual.	☐	☐	☐	☐	☐
2.6 The reflection session helped the students identify how they could	☐	☐	☐	☐	☐

improve their performance for later activities.

2.7 The students seemed eager to partake in the reflection session. ☐ ☐ ☐ ☐ ☐

2.8 Not announcing the scores until the end of the session helped motivate students to pay attention. ☐ ☐ ☐ ☐ ☐

2.9 Students had no problems with identifying how they could improve their performance for later activities. ☐ ☐ ☐ ☐ ☐

2.10 The information available on the website was presented in a good way. ☐ ☐ ☐ ☐ ☐

2.11 Having the students write down what they can do better the next time they use the system will help them become better learners. ☐ ☐ ☐ ☐ ☐

General

	Strongly disagree 1	2	3	4	Strongly Agree 5
3.1 The system made it easier to educate students on this topic	☐	☐	☐	☐	☐
3.2 The system helped me map the academical level of my students	☐	☐	☐	☐	☐
3.3 The system made it easy to include reflection in the teaching process	☐	☐	☐	☐	☐
3.4 I think the students seemed more eager about the subject when using the system (compared to not using the system)	☐	☐	☐	☐	☐
3.5 The system has the potential to increase the students learning capabilities (help them learn how to learn)	☐	☐	☐	☐	☐

What is the best aspect of the system?

What is the worst aspect of the system?

Would you recommend this system, when fully developed, to your colleagues?

Further comments:

Students

Game

	Strongly disagree 1	2	3	4	Strongly agree 5
1.1 I enjoyed playing the game	☐	☐	☐	☐	☐
1.2 AR content did not divert my attention away from the paintings	☐	☐	☐	☐	☐
1.3 AR was a nice way to present information	☐	☐	☐	☐	☐
1.4 The use of AR made the game more fun and interesting	☐	☐	☐	☐	☐
1.5 The use of AR made me more engaged in the game	☐	☐	☐	☐	☐
1.6 I contributed to solving the tasks provided through the system	☐	☐	☐	☐	☐
1.7 The game was fun	☐	☐	☐	☐	☐
1.8 I did my best in order to win the game	☐	☐	☐	☐	☐
1.9 The competitive aspect of the system motivated me to perform better	☐	☐	☐	☐	☐
1.10 I learnt a lot while playing the game	☐	☐	☐	☐	☐
1.11 I used the information provided by the teacher to create questions.	☐	☐	☐	☐	☐
1.12 I searched out information using other sources to make it hard for other groups to answer.	☐	☐	☐	☐	☐

1.13 I found the mobile app easy to use.	☐ ☐ ☐ ☐ ☐

Reflection session

	Strongly disagree 1	2	3	4	Strongly agree 5
2.1 I enjoyed partaking in the reflection session.	☐	☐	☐	☐	☐
2.2 I learnt a lot during the reflection session.	☐	☐	☐	☐	☐
2.3 The reflection session made me realize what I could do better next time I use the system.	☐	☐	☐	☐	☐
2.4 Because of what I learned during this reflection session I will perform better the next time I partake in a similar activity	☐	☐	☐	☐	☐
2.5 I found the material in the reflection session interesting.	☐	☐	☐	☐	☐
2.6 All the data I would like to see after playing was available on the website.	☐	☐	☐	☐	☐
2.7 The score was presented in a good and orderly way.	☐	☐	☐	☐	☐
2.8 Not knowing the score before the end of the session kept me motivated throughout the session.	☐	☐	☐	☐	☐
2.9 The website made it easier to remember my experience from the museum	☐	☐	☐	☐	☐
2.10 The website was easy to use/understand.	☐	☐	☐	☐	☐
2.11 I found it useful to hear how other groups had gathered information to create questions.	☐	☐	☐	☐	☐
2.12 Overall, information was presented in a good way	☐	☐	☐	☐	☐

2.13 By reflecting on the visit I realised how I can learn material more efficiently	☐ ☐ ☐ ☐ ☐

General

	Strongly disagree 1	2	3	4	Strongly agree 5
3.1 I learnt more using the system, than i normally do in class	☐	☐	☐	☐	☐
3.2 I know more about the subject now than before using the system	☐	☐	☐	☐	☐
3.3 I would like to use the system again	☐	☐	☐	☐	☐
3.4 The system made learning more fun.	☐	☐	☐	☐	☐

Comments: