MASTER THESIS

THE INFLUENCE OF PERSONALIZATION ON EDUCATION AND ENJOYMENT IN A MUSEUM

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MSC HUMAN MEDIA INTERACTION

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Abstract

Maintaining the museum integrity as a conserving and educational institution on one hand, and making the museum more competitive and popular on the other hand, is one of the main challenges for museums. This research tried to find out if a newly designed collaborative quest was suitable to be both educative and enjoyable. Special attention was focused on the influence of personal interest on education and enjoyment.

To find an answer, an experiment was conducted in Museon in which groups of four participants, with at least two children, played the quest. The quest started and ended at a multi-touch table, which was used because it was very suitable for collaboration. Between the parts at the table participants had to answer questions, which were provided at terminal computers in the main exhibition of Museon.

Two conditions were compared. Participants in the normal condition got questions about subjects they had indicated as interesting at the start at the table, participants in the inverse conditions got questions about subjects they had not indicated as interesting. It showed that children in the normal condition scored higher for understanding than children in the inverse condition. For remembering and enjoyment no differences were found between the two conditions, but scores were quite high. The collaborative quest showed that it is possible to make a museum visit both educative and enjoyable.

Preface

One of the things I find interesting about Human Media Interaction is using new technology to improve an existing situation. For this research I had the opportunity to work with one of the newest multi-touch tables on the market. I was involved in the development of a new interactive quest through Museon that made use of the table and the existing technological infrastructure. The quest was not only developed to find an answer to the research question in this thesis, but also to be available to all visitors of Museon.

I would like to thank the staff of Museon for all their support and especially my supervisor at Museon, Hub Kockelkorn, for his guidance and help in the development of the collaborative quest. Special thanks to Renske Koning and her family, who offered me a place to stay during the experiments.

Els Koster, Stefan Oldewarris and Alje van den Bosch were very supportive during the completion of this thesis. The first because of all her help regarding SPSS, the last two for their proof reading. Of course I would like to thank my supervisors at the University of Twente and especially Frans van der Sluis and Betsy van Dijk for their guidance and great support.

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Bert Perloy
Enschede, December 2011

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Chapter 1

Introduction

> "Museum. A museum is a non-profit, permanent institution in the service of society and its development, open to the public, which acquires, conserves, researches, communicates and exhibits the tangible and intangible heritage of humanity and its environment for the purposes of education, study and enjoyment."

The quote above is from the International Council of Museums [1] and contains the definition of a museum. A museum has three goals: education, study and enjoyment.

Museums have to compete more and more with other educational; focusing on both education and entertainment, and cultural centers and activities [12]. One of the things museums have done to deal with this is making use of (recent) technology. They hope to make the museum visit more complete and more entertaining, and to increase the visitor numbers [23][28]. Making use of personal technology can personalize a museum visit, make it more interactive and give visitors immersive experiences. The accent of museums shifts more towards enjoyment, making the traditional museum more of a hybrid place, where education and recreation are both important [34][56].

1.1 Museon and PuppyIR

This research has been done for Museon, a science museum in the Hague, the Netherlands. Museon is an educational museum for a broad audience and the main themes are the human and his role in society, nature, culture, science and technology. Museon has 160.000 visitors each year, the majority of these visitors are families. These families are mostly composed of one or two adults and one or more children. The age of the visitors varies from four years old till above 80 years old.

Museon has one permanent exhibition, called Your World, My World. Visitors can discover for example how life came to be on Earth or how energy is stored. But also the relationship between Barbie and religion can be found [38]. In the exhibition space many terminals, about 120, are available. A terminal is a computer with a touch screen and a barcode reader. Visitors can scan their entrance ticket, on which a special code is printed, to get access to personal content. Appendix C shows a map of the museum.

Museon is a museum with the goals education, study and enjoyment, according to the given definition. It also faces the challenge of finding the right balance between education and enjoyment. The available terminals are currently only used for information provision. Together with a new multi-touch table, Museon wanted to use their technology with a surplus value for the visitors. Their wishes were that the focus was on collaboration and that the story behind the items in the collection of the museum should be told to the visitor. This research deals with this problem, with a focus on education and enjoyment.

1.1.1 Multi-touch table

One of the wishes of Museon is the use of a 46 inch (117 cm) multi-touch table, because of its expected positive contribution to collaboration. A multi-touch table is a horizontal surface display that can register multiple concurrent inputs. The interaction is directly on the display, making the manipulation of objects direct and intuitive. Because of the interaction with a large display, all users can see what others are

doing, something that improves the communication. Because multiple concurrent input is detected, it is more likely that all users contribute to the interaction [48].

In earlier research, single- and multi-input devices have been compared. Stewart et al. [57] investigated cooperation behind a single screen with one or two input devices. A usability test with Kidpad, a multi-user drawing application, was conducted. Groups consisting of two children, aged 8-12 years, had to draw a picture with one shared mouse or two individual mice. Children found two input devices easier and more fun to work with. Fun was more important than efficiency of task completion. Children indicated that they preferred to work with multi-input devices because there was no turn-taking and they could work in parallel. This indicated that working together is easier when there are more input devices, like on a multi-touch table.

In Stewart et al. [58] the focus was again on the influence of multi-input devices on cooperation. This was tested with a system, KidPix. Two children had to draw a story using one mouse or two mice. The single-input variant caused more frustration and a lack of attention, and the quality of communication was less collaborative. In the multi-input variant the kids had more fun and collaboration was supported. These findings can likely be mapped to multi-touch tables.

Harris et al. [13] tested the difference in a design task on a table with single-input and a table with multi-input. The focus was on collaboration. Subjects, aged 7-10 years, had to design a seating plan for the classroom on a tabletop. Children in the first condition had to work on a single-touch table and children in the second condition on a multi-touch table. The condition did not affect the frequency or equity of interactions, but did have influence on the nature of children's discussions. In the single-touch condition the children talked more about turn-taking. Also more frustration was observed. The multi-touch condition contained more task-related talk. The attention was more on the task itself, when using the multi-touch condition. Because of this, the multi-touch condition seemed to strengthen the relevant collaboration.

In the discussed papers multi-input devices were found to be good for collaboration, enjoyment and task-efficiency. This supports the initial assumption of Museon and makes the table suitable for the research.

1.1.2 The puppyIR project

The research in this thesis is part of an international research project, puppyIR [42]. When searching for information on the internet, most will use a search engine, like Google or Bing. But these search engines are developed for adults, and not always suitable for children [21]. PuppyIR is filling this gap, by, as can be found on their website, "constructing an Open Source Framework that will provide the infrastructure to develop 'child-focused' and 'child-friendly' components to be deployed within child information services" [41].

One aspect of the project is interaction. How can suitable information be presented to children, so that they can understand and work with it? Is a personal computer sufficient for children, or is there other technology that can be used? These are some questions that are still open and puppyIR is trying to find answers to them.

In this research project an implicit form of searching and a quite new technology, the multi-touch table, are used to make a contribution to the project.

1.2 Museum-going experience

As can be extracted from the definition of museum, education, study and enjoyment are important. Kotler and Kotler [24] observed that museum managers have to find a balance between those three. On one hand they want to make the museum more competitive and popular, on the other hand they want to maintain the museum's integrity as a conserving and educational institution.

Improving the museum-going experience is one of the strategies defined by Kotler and Kotler for a museum to reach their goals. The museum-going experience is the complete experience the user is expected to get during his visit and improving the museum-going experience means maximizing the museum's goal of enjoyment, study and education. Kotler and Kotler identified what could be done to improve the museum-going experience. The following list gives an overview of these things. Service-based points like availability of convenient parking and ease of physical access to the museum building

are outside the scope of the research in this thesis and are therefore not treated.

- **Duration.** The casual visitor spends around an hour in the museum [24, 51]. This average spending time differs for each museum, but it gives an indication. The average time spent in Museon is higher, about two hours.
- **More than spectators.** Visitors want to be more than spectators. Museum visits can be made memorable and unique by creating environments in which visitors can immerse themselves [24][36].
- **Part of group/ collaboration.** Museum visitors are mostly part of a group, like family or friends. The behavior of this group is dependent on the interests and attitudes of the whole group [24]. Visitors find social and recreational experiences as important or even more important than intellectual and educational experiences [24].
- **Personal relevance.** Visitors have their own agendas, and visit a museum the way they want. They prefer museum activities with which they can connect in an easy manner, activities that are relevant to themselves [24]. In Chapter 2 is explained how education and enjoyment are linked to personal interest and why it is important to make a museum visit personally relevant.
- **Guiding.** It can be hard to find one's way in a museum for first-time visitors. To solve this problem, large museums offer maps of galleries and exhibits [24]. Another problem is museum fatigue [7]. This is the phenomenon that visitors pay less interest in exhibits as the visit progresses.

All these concepts are to a greater or lesser extent important when improving the museum-going experience. Personal relevance, guidance, immersion and collaboration are things a visitor finds important when visiting a museum. Study, enjoyment and education are the goals of the museum. Picture 1.1 gives a schematic overview of the relation between the goals of visitors and the goals of the museum. Improving the first four concepts improves the museum-going experience and helps a museum to reach their goals.

1.3 Collaborative quest

The main problem of this research project is that it is hard for a museum to find the right balance between education and enjoyment. Both education and enjoyment are influenced by personal interest, which is covered in more detail in Chapter 2. Taking education, enjoyment and personal interest into account, a collaborative quest was designed. This is an interactive guide through the permanent exhibition My World, Your World.

The quest consists of three parts. Visitors start with a group of three/four at a multi-touch table. They personalize the quest by making a selection from the exhibits of My World, Your World, by picking related images. This helps visitors to get an overview of the collection. With the selected exhibits as input, personalized routes through the exhibition are generated, giving visitors some guidance. This part will be referenced to as the begin part.

The second part, the middle part, is in the exhibition My World, Your World. A visitor scans his personal entrance ticket at one of the terminals. In response a question about one of the earlier selected exhibits is shown. The visitor can find the answer at that exhibit. Eventually all group members have answered their questions and return to the multi-touch table. In this last part, the end part, they can play a final game, that tests the knowledge gained by the group.

The focus of the research is on the design of the quest in general and the accompanying applications running on the multi-touch table. For the general design collaboration, education, enjoyment and personal relevance are important. The target audience are visitors of Museon, who can play the quest in groups of three or four people.

1.4 Motivation and research question

A new kind of quest was developed, to improve the museum-going experience of Museon's visitors and help Museon reach their goals. The following overview gives the motivation behind the quest and indicates the topics the quest aims to improve.

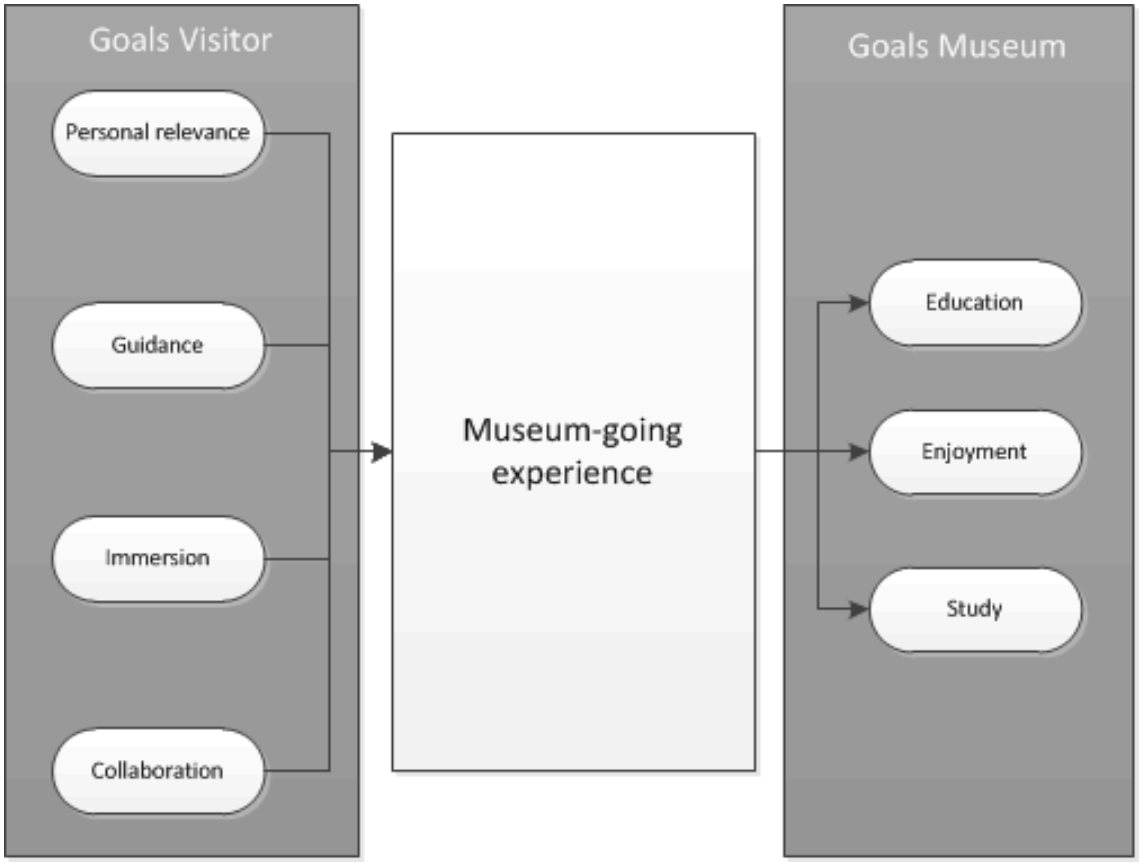


Figure 1.1: Goals of visitor and museum linked to museum-going experience.

- Visitors can feel lost in a museum, the collaborative quest should give the visitors guidance, by providing them a route through the museum based on interest.
- Museum fatigue causes visitors to move faster through exhibits when they are longer in the museum. The quest helps them to divide their attention over the whole exhibition.
- Museum visitors are mostly part of a group. The collaborative quest should be suitable for groups, with a focus on collaboration.
- The use of the technological infrastructure, especially the terminals, of Museon is currently not optimal.
- The museum should be competitive with other cultural centers and activities, but education is still an important goal. Both education and enjoyment are linked to personal preferences. The collaborative quest should use the personal preferences (personalization) to create an educational and enjoyable activity, that is personally relevant.

Taking these motives into account, the research question is formulated:

> *"Can the educational and fun experience of a museum visit be enhanced by personalization?"*

Requirements are the use of a multi-touch table, terminals and an accent on collaboration. The research question is very broad, so the following sub questions are used.

1. Is there a noticeable influence of personalization on the enjoyment of museum visitors?
2. Is there a noticeable influence of personalization on the education of museum visitors?

Besides these questions, three other questions are used to check the requirements.

3. Do people collaborate while they do the quest through the museum?
4. Are a multi-touch table and terminal computers suitable to be used in a quest through the museum?
5. Is the quest through the museum suitable to give guidance?

From this research question and sub questions four constructs are extracted: enjoyment, education, collaboration and personal interest. In Chapter 2 the theory behind these constructs is given.

1.5 Outline of research

Chapter 2 gives a theoretical framework of the four important constructs of the research. Chapter 3 contains information about the implementation of the quest and the developed prototype. This prototype is used in an experiment which is described in Chapter 4. The results of the experiment can be found in Chapter 5. In Chapter 6 the results are discussed and this chapter ends with recommendations for future research and a final conclusion.

Chapter 2

Theoretical framework

In this chapter theoretical background information about the four main constructs education, enjoyment, collaboration and personal interest is given. For each construct theoretical information is given and linked to the collaborative quest. The chapter concludes with hypotheses, which are drawn from the collected information.

2.1 Education

Education is one of the main goals of Museon. Originally museum education was limited to 'taught' lessons for school children and tour groups. Those are still important, but museums can do more for education. Exhibitions, displays, events and workshops can be used to educate visitors [17]. The educative material that is available in Museon is the collection in the exhibit My World, Your World, so in this case the exhibition is used for education.

This section looks at age-related limitations, the three major learning theories and the three domains of educational activities. The information obtained from the theories is used to design the educational part of the quest.

2.1.1 Age-related limitations

The target audience of the quest are families with children. Jean Piaget, the Swiss psychologist, believed that certain ways of thinking were more difficult for children than for adults. According to Piaget, people pass through four different stages, the four stages of cognitive development. The first stage is the sensorimotor stage (0-2 years), the second is the preoperational stage (2-7 years), the third the concrete operational stage (7-11 years) and the last one the formal operational stage (11-adult). In the first two stages, children are able to think operations through logically in one direction and have difficulties seeing another person's point of view.

In the concrete operational stage, children are able to solve concrete problems in a logical fashion, understand laws of conversation, are able to classify and seriate, and understand reversibility. In the formal operational stage children become more scientific in thinking, are able to solve abstract problems in logical fashion and develop concerns about social issues.

One limitation of Piaget's theory is the strict divisions between the stages. The thinking process is continuous and not the same for everyone. It also appears that Piaget underestimated the cognitive abilities of children and overlooked cultural factors. Psychologists agree that children go through the changes described in the stages, but it is not a perfect guide [62].

2.1.2 Learning theories

Behaviourism, cognitivism and constructivism are three major theories on the topic of learning. These theories describe how people learn. The information given by these theories was used in the development of the collaborative quest, to strengthen the learning effect.

Behavioural learning Behavioural learning is a learning type where external events are seen as the cause of changes in observable behaviours [62]. Several non-exclusive views on behavioural learning exist. One of these views is operant conditioning, developed by Skinner. Operant conditioning is about reinforcements and voluntary behaviour. Antecedents are events that precede an action and consequences are events that follow an action. From the relation antecedent - behaviour - consequence people can learn. If you are for example tired (antecedent), you can choose to sleep (behaviour). This might result in feeling awake afterwards (consequence). From this consequence you have learned that it helps to sleep when you are tired. Consequences can be used to strengthen or weaken behaviour. This is called reinforcement. In positive and negative reinforcement something positive is added or something negative is removed. Punishment is the opposite. Something negative is added or something positive is removed. The first form, adding something negative, is very effective, but there are doubts if it is a good thing to do [11]. One of the problems is generalization. Children can associate other stimuli with the punishment stimulus and make the same response to these associated stimuli.

Another view is observational learning [62]. Albert Bandura thought that earlier learning views were accurate, but gave only a partial explanation of learning. Especially social influences lacked in the traditional views. He developed a new theory, the social learning theory. In this theory people can learn by observing other people. An extension of the social learning theory is the social cognitive theory. It adds cognitive factors as beliefs, expectations and self-perception. There are two variants: enactive and vicarious learning. The first one is like operant conditioning. Where in the operant conditioning theory consequences reinforce behaviour, in enactive learning, consequences provide useful information that can be used for future decision making. Vicarious learning is learning by observing other persons being reinforced for behaviour.

Cognitive view of learning The second theory is a cognitive view of learning. In contrast with behavioral learning, where people learn new behaviours from responding, the cognitive view is about the people themselves, who are constructing their own learning.

Learning is seen as an active mental process where knowledge is acquired, remembered and finally used. With new knowledge it is possible to change behaviour. The difference can also be seen in the reinforcers. In behaviourism they strengthen or weaken the responses, in cognitivism they serve as feedback about what is likely to happen when something will be done again or avoided. So a reinforcer provides new information that can be used for future decisions.

Cognitivism makes use of schemas. Knowledge is stored in schemas, internal knowledge structures. When someone receives new information, the information will be compared to existing schemas. The schema tells the person what he can expect from a situation or object. An existing schema can be combined, altered or extended to accommodate new information [35]. Coherent to this is the concept of meaningful effects. People remember and learn information that is meaningful to them easier.

Constructivist view of learning The last theory is the constructivist view of learning [62]. It has its roots in the cognitive view of learning, but has moved beyond. Constructivism is about the personal and active construction of knowledge. A person has his or her own perceptions and experiences. These are interpreted and with the interpretation an own reality is constructed. So prior experiences, beliefs and mental structures that are used to interpret objects and events determine ones knowledge. This is done actively [35]. The process of social interactions shares the realities of different persons with each other. This emphasizes the importance of collaboration.

For the construction of knowledge some things are important. Marlowe and Canestrari [31] pointed out the difference between shallow and deep knowledge. With shallow knowledge only conclusions or facts are remembered, not the connection between those two.

2.1.3 Domains of educational activities

There are three domains of educational activities [6, 32]. The domains are cognitive, affective and psychomotor. The cognitive domain is about mental skills and often referred as the Knowledge domain. Affective is about growth in emotional areas and feelings (Attitude domain) and psychomotor about physical or manual skills (Skills domain). Attitude and Skills are outside the scope of this research.

The cognitive domain is divided in six major categories and is referred to as Bloom's Taxonomy of the Cognitive Domain. The taxonomy was updated by a group of cognitive psychologists, lead by

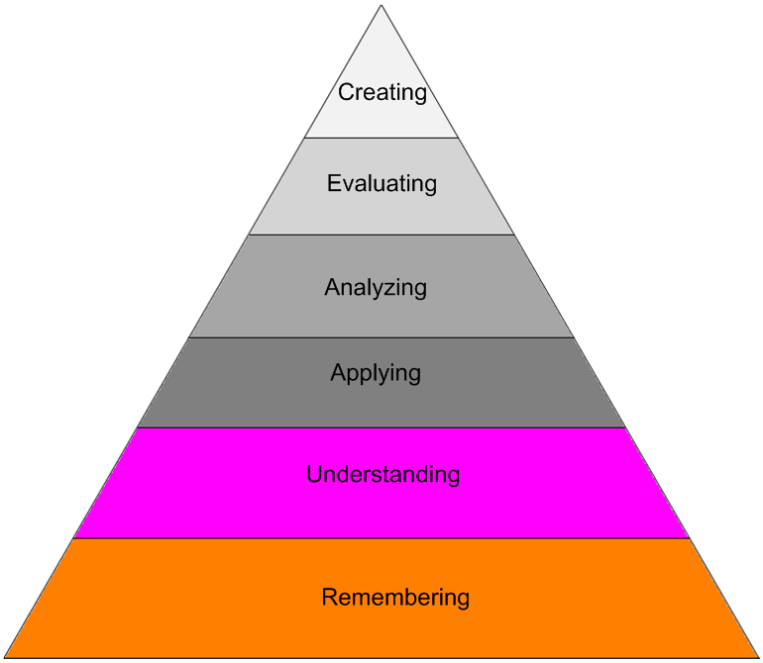


Figure 2.1: Bloom's Taxonomy of the Cognitive Domain. The first two levels were used in this research.

Lorin Anderson [10, 25]. The new version, which is showed in Figure 2.1, is used in this research. The important categories for this research are *remembering* and *understanding*. *Remembering* is about retrieving, recognizing, and recalling relevant knowledge from long-term memory. *Understanding* is about constructing meaning from oral, written, and graphic messages through interpreting, exemplifying, classifying, summarizing, inferring, comparing, and explaining.

2.1.4 Education in the quest

Based on the four stages of cognitive development, the quest is designed to be suitable for children older than seven years of age, but this is not a strict limit. Questions in the quest are not suitable for children younger than seven years, because concrete operational stage skills like classification and seriation are required. In the Netherlands children learn to read and understand sentences from the age of seven [22]. That is also important because participants should be able to read their questions without help.

The quest uses the principle of reinforcement. At the start of the game participants are told to have fun and to do their best so they might get a high score. This is mainly a performance goal, which is not the best goal for education. Mastery goals are better, but harder to use in this setting [62]. During the quest each participant has an individual score and there is a common group score. An incorrect answer is punished with a lower individual and group score, a correct answer rewarded with a higher individual and group score. The group score is used to stimulate cooperative learning. This score reminds the group members that they are linked with each other. If they coordinate their efforts, the likelihood to accomplish the task (getting a high score) increases. People can learn by watching others, for interaction and content purposes. The multi-touch table helps with this, because one of the strong points of the table is simultaneous interaction.

After each answer feedback is given. The participant is told why the answer was correct or incorrect. Feedback on incorrect answers helps visitors to remember correct information, because otherwise incorrect information can be remembered as correct [31]. With this extra background information the quest provides information that makes it possible to obtain deep knowledge and not only shallow knowledge. This helps the users to understand the information (*understanding*) and not only remember the factual information (*remembering*). The stimulation of finding the answer in the exhibition also helps. So individual knowledge is actively constructed in the question-answer part, with the possibility to share information. The final game stimulates to share the gained knowledge, helping each other constructing knowledge.

From cognitivism it is expected that a personalized quest has a positive effect on learning. This is also supported in Renninger et al. [46]. Children and adults with an interest in an activity or a topic persist for longer periods of time, pay more attention, and acquire more knowledge than children or adults without that interest.

2.2 Enjoyment

One of the goals of a museum is enjoyment. There is no single definition of enjoyment and it is often interchangeably used with terms like pleasure and fun. In Blythe and Hassenzahl [3] the differences between enjoyment, fun and pleasure are described. Concluded is that none of the terms are reducible to single definitions and that fun and pleasure are two distinct types of enjoyment. Fun is about distraction from one selves, from ones concerns and problems. Pleasure is deeper, it focuses on an activity and gives a feeling of absorption. So fun can be used to make repetitive and routine work more enjoyable. Pleasure, with its focus on absorption, can make non-routine and creative work enjoyable.

Lin et al. [29] gave an overview of several definitions of enjoyment. In psychology for example Davis expressed the view that "A is enjoying E, if E is causing A to have a number of occurrent beliefs concerning E, which collectively add significantly to the pleasure (happiness) A is experiencing". They conclude that all the definitions provide a basis for the following definition of enjoyment: "The meeting and fulfillment of a person's needs." This is the definition that is used for this research.

Vlachopoulos and Karageorghis [61] mentioned that feelings of enjoyment are a consequence of intrinsically motivated behaviour. The connection between enjoyment and both intrinsic and extrinsic motivation is also made in Reeve [45]. It focuses mainly on the difference between enjoyment and interest in intrinsic motivation. The conclusion is that enjoyment contributes to intrinsic motivation by sustaining the willingness to continue and persist in an activity. This is the exact opposite of what was said in Vlachopoulos and Karageorghis [61], where enjoyment was a consequence of intrinsically motivated behaviour. Notwithstanding that, there seems to be a strong connection between motivation and enjoyment, so more information on motivation is given below.

2.2.1 Motivation

The definition of motivation given in Woolfolk et al. [62] is "An internal state that arouses, directs and maintains behaviour." An important aspect of motivation is the positive relation with time spent in activities. Motivation can be intrinsic and extrinsic.

Intrinsic motivation is associated with activities that are their own reward. The activity itself is interesting or enjoyable, so people are motivated to engage in the activity for its own sake [20]. Several approaches to intrinsic motivation exist [62]. The humanistic approach to motivation was one of the first theories that explained why people act as they do. The approach is about encouraging people's inner resources. A person aims at successful personal development and needs self-determination. The need for competence, control and relatedness are basic in people. This can be used in teaching. Expectations should be clear and achievable, and choices help increasing the perception of control and autonomy. Personalized examples are good for relatedness. The sociocultural view of motivation focuses on the concept of identity. People find their identities and interpersonal relations within a community important. They participate in activities to maintain those identities and relations. For example, people are motivated to learn if they are at a school that values learning [62].

Extrinsic motivation is motivation created by external factors like rewards and punishments. Someone who is extrinsically motivated is interested in what he can gain with an activity, not the activity itself. Rewards and incentives are used to motivate. A reward is supplied as a consequence of a particular behaviour and can be an attractive event or object. An incentive is given before a particular behaviour, hoping to encourage or discourage that behaviour. An example of this concept is giving a grade. A student might not like a course, but only works hard for a good grade (reward). The student is extrinsically motivated. Tangible rewards like candy or grades can be used to motivate people, but verbal rewards like praise undermine interest less (both cause a decrease in intrinsic motivation). Verbal rewards that provide information are effective, those that attempt to control behaviour are not. Holbroock et al. [16]

tell that positive feedback concerning success actually increases intrinsic motivation and self-reported enjoyment. Saying things like "good job" can be dangerous [31]. It is better to say nothing, say what you saw or ask questions. When using praise it should be about the effort that children put into a task and not about their intelligence.

Several motivational techniques for classroom teaching are mentioned in Gage and Berliner [11]. It is important to give children a reason to be motivated. This can be done by telling what they are going to do and why it is interesting and enjoyable. It is also important to give them a clear goal. An example of where this went wrong was in an exhibition of the Berlin Museum of Natural History [18]. The museum accommodates the Tree of Life table. This is a 75 cm high table, with a 1.15 by 2.15 meter surface, on which an image is projected. Using capacitive sensor technology, the table is suitable for multi-touch. Four species related questions are displayed on the table. When touching them, the answer appears. The table can be seen as a sort of interactive information browser. One of the main critics on this exhibition was that the purpose was not clear. Without knowing the purpose, people are missing an incentive to persist in interaction [31]. Another thing that can be motivational is the use of familiar material for examples. Familiarity, associations and meaningfulness can improve retention and learning. A last point is to use what children have learned before.

2.2.2 Flow

Sweeter and Wyeth [59] described a research about enjoyment conducted by Csikszentmihalyi. He asked over a thousand respondents why experiences are enjoyable and found that optimal experience, called flow, is everywhere on the globe the same. The participants in his research described the different activities they found enjoying, in the same ways. One of his conclusions was that enjoyment (or more specific pleasure if the distinction from Blyth and Hassenzahl [3] is used) is the same regardless of age, gender or social class. He described flow as "an experience so gratifying that people are willing to do it for its own sake, with little concern for what they will get out of it, even when it is difficult or dangerous".

Flow experiences are composed of several elements, which when combined give a sense of deep enjoyment. The first element is that the task can be completed. The task should also have clear goals and should provide immediate feedback. People should be able to concentrate on the task and exercise a sense of control over actions. The last three elements are about immersion. In flow people experience a deep but effortless involvement that helps them forget the frustrations of everyday life. The concern for self disappears during the activity and the sense of duration of time is altered. When an activity fulfils these elements, people experience it as enjoyable.

2.2.3 Enjoyment in the quest

There does not exist a single manual that describes how an activity can be made enjoyable. People who are intrinsically motivated will engage in an activity. Giving users familiar examples, choices, and clear and achievable expectations helps people to become intrinsically motivated. The quest provides those by letting the user choose their own subjects and by giving a clear and reachable goal.

The quest provides extrinsic motivation as well. After a correct answer a user earns points and the system tells the user he did well. After an incorrect answer the user is punished by giving him or her penalty points. The user is then stimulated to find the correct answer. In the final game the same principle is used. The purpose of the final game is to make connections between items and keywords. Each good connection is rewarded with points and each wrong connection punished by subtracting points.

Another way to make the quest enjoyable, is to fulfill the elements of flow. The quest can always be finished. If users are stuck in the question-answer part, team members can help them or they can just guess the answer. After three tries the correct answer is given and the user can continue with the next question. The goal of the quest is given at the table and repeated at the beginning of the question-answer part. After every action feedback is given. Some feedback is only given for fun. For example at the start at the table, when the table is touched, bright colors and sparkles are displayed. By giving the users the choice to determine the content of the quest, the user is given the feeling he or she is in control. The immersive elements and concentration element are harder to control. The quest provides the users during the whole quest with things to do. They start with creating their quest, and should actively look

for answers in the exhibition. Finally they can show their team members what they have learned. By keeping users busy all the time and let them explore the museum, the quest should become immersive and together with the fulfillment of the other elements of flow, enjoyable.

2.3 Collaboration

The learning theories implied that working together has benefits for learning. In Woolfolk et al. [62] three variants of working together are mentioned; collaboration, cooperative learning and group work. And although collaboration, cooperation and group work are often used interchangeably, they are different concepts. Cooperation can be viewed as a way of learning by talking and working together to share thoughts. Collaboration is agreed behaviour contributing towards reaching a shared goal. When people work together, it is called group work. In group work people can collaborate or cooperate, but they don not have to. So for example, a group of five people is allocated a task. They do not work together and one person does all the work, but it is still group work. When they discuss the task together to solve the problem they cooperate. They can also divide the task in subtasks, work independent on them and assemble the outcome. This is collaboration.

Collaboration is the main concept for the collaborative quest. A team starts with the common goal of getting a good group score, but the individual group members have their own tasks. They can cooperate, but they do not have to. Collaboration is necessary to reach the common goal. For the parts at the table the group has to cooperate. The rest of the section treats cooperative learning, which shows the advantages of cooperation in the area of learning. After that several examples are given of how technology in museum helps stimulating collaboration.

2.3.1 Cooperative learning

Gage and Berliner [11] support the statement that working together has benefits for learning. They say that cooperative learning has a positive effect in learning. In cooperative learning small groups of students work together for group rewards. One of the advantages is that higher-ability children can help lower-ability children, helping each other with learning. The higher-ability children, however, should not be restricted by this. With one common goal, group members can help each other, but each individual should also be challenged on his own level. The positive effect of better involvement was demonstrated in Cappelletti et al. [4]. Children got the task to create a story together. Before the task, they had to tell an individual story, for comparison. The result was that the cooperation had a positive effect on involvement. However, the quality of work scored lower. This was probably because it is harder to create a story together than alone.

In Cappelletti et al. [4] several main tenets are given for cooperative learning. Positive interdependence must be established among children. The result of this is that children feel linked with their group mates. They can only succeed if their group mates do, they have to coordinate their efforts with the efforts of their group mates. When done well, they can accomplish the task. Positive interdependence itself consists of several facets. With positive goal interdependence the group and individual group members have the same goal. In positive resource interdependence the focus is on resources. Only limited resources are available and have to be shared with the whole group. Individual performance can be provided, by showing for example a score, in order to stimulate the individual accountability and personal responsibility.

2.3.2 Technology and museum exhibits

In several museums, technology is used to stimulate interaction. At Tate Britain, the national gallery of British art from 1500 to the present day, the exhibition “ Johan Constable: The Great Landscapes” was displayed in 2006. In this exhibition the so-called technology X-Ray examination was used. Hidden pieces of the original sketch of the painting became visible on the screen when people moved in front of the painting, that was displayed on the screen. The people could explore the differences between the original sketch and the final painting [28]. The interaction was very intuitive and all interaction was

visible to others. Though it is possible to interact simultaneously, this was not done in this exhibit. People watched others interact with the painting, they are called public. After the current user moved on, someone from the group of public became the next user.

Peltonen et al. [40] showed that it is also possible that strangers interact simultaneously, but on their own private spaces. In Helsinki a vertical 2.5 meters wide multi-touch screen was installed in a shop window. The screen could be used from outside. On the screen photos could be viewed, rotated and resized. The screen was mostly used by more than one person, both collectively and parallel. With parallel use, users had their own private space and tried not to disturb other users. Collective use was using the whole screen with a group of people. Making the interaction visible to others is positive for learning. People can see that it is possible to interact and how things work, by watching others. Collaboration between people and their creativity led to unexpected behaviour. Instead of using the application as a photo viewer, people played the game Pong by throwing photos to each other.

Deus Oculi and Ghostship [15] are two exhibits that need collaboration to discover the full potential. Deus Oculi, exhibited at Chelsea Crafts Fait consisted of a main picture that displayed a Renaissance scene. On both sides are two fake "hand-mirrors" located. The Renaissance scene is made of two people, a man and a woman. On the places of their heads are holes, with monitors behind each of them. Cameras hidden in the hand-mirrors sent images to the monitors. If someone is looking at the mirror, his head is embedded in the painting in the middle. The exhibit provoked a lot of interaction and discussion between visitors. The same thing was done for Ghostship, but this time on a larger scale. People needed other visitors to find out all the options of the exhibit, with only two or three people it was hard to discover everything.

The setting and surroundings of an exhibit can help to stimulate collaboration. In Nottingham Castle, exhibits Storytent and Sandpit were designed to support collaboration [2]. Storytent was a place in the shape of an A-frame tent. Inside the tent, visitors had to place paper clues on a turntable. After placing the papers on the table, the display was triggered showing a 3D historical reconstruction. By rotating the turntable, a 3D panorama and related paintings could be viewed. Inside the tent multiple seats were placed to support interaction with more than one person. For Sandpit the same thing was done. Sandpit is a virtual sandpit, projected on the floor. By shining flashlights on it, users could dig for images. By placing paper clues in a nearby sandbox, the images in the sandpit changed. With multiple flashlights, the exhibits intention was also collaboration between visitors.

2.3.3 Collaboration in the quest

Collaboration is stimulated directly at the start of the quest. First of all, the quest is only suitable for three or four players, but that can make it just group work, without any collaborative or cooperative elements. Next the multi-touch tables physical shape requires the users to stand around the table. Not all the explanation texts on the screen are offered to all group members. In most cases there is only a single instance. The users can choose to read the text one by one, but the idea is that they help each other and one team member reads the text aloud. Around the table is enough space for public, who can join a group or just can see what the other group is doing.

The concept of the quest stimulates collaboration, because a common goal is given where the knowledge and skills of all users are necessary for the final result. Incorrect answers not only influence the individual score, but also the group score. To get a good team score, efforts have to be coordinated and collaboration can be helpful. In the final game the knowledge of all team members is needed to get the best result.

2.4 Personal interest

Personal interest is highly related to enjoyment and motivation. Reeve [45] described that interest and enjoyment both have differential contributions to (intrinsic) motivation. Interest helps people to start with an activity. It arouses the initiation and direction of attention and exploratory behaviour. After that enjoyment helps people to continue and persist in the activity.

In Hidi and Harackiewicz [14] interest is divided in personal interest and situational interest. Personal interest is a relatively stable motivational orientation, develops over time and is related to a particular domain or topic. It is associated with increased knowledge, value and positive feelings. Stimuli in the

environment generate situational interest. The consequence is an immediate affective reaction, that can last, but does not have to. Where personal interest is linked to enjoyment and liking, situational interest is not necessarily linked to positive feelings. For example someone can find a tarantula interesting, but does not like the spider. But when situational interest persists, also positive emotions can arise. According to Hidi and Harackiewicz [14] several investigations have shown some differences between children and adults who are interested in specific activities and children and adults who are not. The first group persists longer in the activity, pays closer attention, learns more and their enjoyment is greater.

In Hsi and Fait [19] an example of a museum is given, that made the visit more personal by making use of personal physical items. Each visitor got a personal RFID card, which they can use at several exhibits. At the exhibit "Heat Camera" visitors were able to see thermal images of themselves. With their RFID card, they could trigger a camera to take a picture of the scene. With their ID card number, they had access to these pictures, at the museum or at home. Concluding, identification technology was used to identify visitors and offer them personal content.

2.4.1 Personal interest in the quest

All the participants get a personal identification ticket at the start of the quest. The ticket links the table to the terminals in the exhibition. Each group member has to choose his/her own, personal items at the table. They can choose between items that represent parts of the exhibition. With the items a personal route is generated, that correlates to the items the visitor found most interesting. The personal ticket is used to get access to individual question at the terminals.

2.5 Hypotheses

In chapter 1 the main research question and related sub questions are defined. Based on the theory in this chapter, the following hypotheses are presented.

Sub question 1: Is there a noticeable influence of personal interest on the enjoyment of museum visitors? Two variants for the quest are developed. One uses selected items, the other one uses the remaining items. According to the theory enjoyment is greater in activities people are interested in than in activities they are not. This leads to the following hypothesis:

H1: The reported enjoyment will be higher for the variant that takes personal interest into account than for the one that does not.

Sub question 2: Is there a noticeable influence of personal interest on the education of museum visitors? People remember and learn information that is meaningful to them easier and learn more from activities they are interested in. Expected is that visitors learn more from the variant that uses the personal interest than from the other variant. This leads to the following hypothesis:

H2: Visitors learn more from the variant that takes personal interest into account than from the one that does not.

For the other three sub questions no hypotheses are drawn. Those questions will be answered using qualitative data.

In the next chapter the prototype used for the experiment is described.

Chapter 3

Development and implementation

To find out if the concept of the collaborative quest worked and to get answers on the research questions, an experiment was conducted. For this experiment a prototype of the quest was implemented. This chapter describes the final implementation of the prototype. Research to several aspects of multi-touch is conducted and the first part of this chapter gives an overview of this. The second part of the chapter describes the prototype, which took into account the findings of the multi-touch literature.

3.1 Multi-touch guidelines

Multi-touch tables are a relatively new technology. Unlike for example mobile websites, there are no clear design guides for multi-touch tables. But there is quite some literature written about experiments using multi-touch tables. This section summarizes the recommendations from that literature. The results are used as guideline for the quest. In Section 3.3 the guidelines are linked to the prototype.

Workspaces On multi-touch tables multiple users interact simultaneously. In Rick et al. [47] research was done to find out how children work together at a multi-touch table. An experiment was conducted whereby children had to allocate where students in a class should sit. On each table there was space for three students and there were several restrictions. The children could drag the students to a table, allocate them to that position. One of the important findings was that children work mainly in the area in front of them. Children positioned at the left short side of the table did less, because they are often right-handed and get in the way of the children positioned right of them. In contrast to adults, children used the whole surface of the table, they touched all of the table. Also arms were freely moved across arms of other children, this in contrast with adults.

In Scott et al. [54] two observational studies have been conducted to gain more understanding of natural interaction practices involving tabletop interfaces. Traditional media like pen and paper were used in the studies, and with the results relevant design implications were drawn. The first design implication was the provision of visibility and transparency of action. This can be important if additional smaller screens for private use are available. The second implication was that every user should be provided with appropriate table space, which supports the findings in Rick et al. [47]. With individual tasks, every user should have enough space, but with a collaborative task, a small individual workspace and with that a larger collaborative space, can be better. A last useful implication was about functionality that should be provided in appropriate locality. A button that affects all, should for example be placed in the center. This way every user has the opportunity to participate in the decision of pushing the button.

Orientation One of the challenges in designing for multi-touch tables is orientation. Unlike a computer screen, a multi-touch screen has no fixed viewpoint. In Kruger et al. [26] research was done to the usage of orientation on tabletops. Existing tabletops used several approaches for orientation. Fixed orientation uses a single, fixed orientation. Manual orientation lets the users rotate items manually. Person-based automatic orientation rotates items automatically towards the person who has most recently touched the item. Because the table is not always aware of the location of users, the last approach tries to

solve this. Environment-based automatic orientation rotates items in the direction of the closest edge. The assumption is that the person who is closest to the item, should have the best view on it. In the paper these and other approaches of orientation are investigated. With the observational data, several implications for design are given. The first one is that users should always have the option to rotate items freely. When items are automatically rotated, the user should have the option to override this and place the item according to their wishes. The next one is that when a user has positioned an item, that orientation must be maintained. The last one mentions that rotation actions must have clear feedthrough; it must be clear to other users when a user is performing a rotation action.

Ryall et al. [50] supports that there is no single solution for orientation. When users are around the table, they have different views on the surface. For small chunks of text this was not a problem, for large amounts of text orientation was more important.

Multiple users With multiple users who can interact simultaneously, it can be helpful to use coordination schemes. Morris et al. [37] researched multi-user coordination at a tabletop. The main focus is on working with documents, but some conclusions are still interesting. Several global coordination policies were tested, from which voting was the most interesting one. If there is a global change on the table, a change that affects all the users, each group member can vote against or in favour of the change. Voting can be used to give all members an equal vote. There were also some policies for element coordination. Element coordination is about elements displayed on the table, which can be claimed by more than one person. In the public variant there are no restrictions, everyone can access an element. The stalemate variant makes an element temporarily inactive if someone attempts to take an element from someone else. The last variant is speed and force. The user who applies the most speed or pressure on an element, will get the element. One conclusion was that elements on a walk-up and use table in a museum, like the multi-touch table in Museon, should not have a policy. Controlling access is not desirable in this setting because none of the table elements belong to a specific user.

Ryall et al. [49] conducted an experiment to find out what the influence of table size and group size are. Participants were given a poem on paper. This poem had to be reconstructed on a multi-touch table, making use of single words. The results were that the size of the table had no significant effect on speed, but group size had a significant effect on speed. Larger groups were faster in their task than smaller groups. It was tested with groups of two, three and four people. Other interesting findings were that participants did not grab words that were near a partner. For large groups it can be interesting to extend the surface with additional vertical displays, where shared information can be displayed on.

Interaction Ryall et al. [50] have observed four interactive tables in non-controlled settings. The table they used was the DiamondTouch. The first setting was a lobby table and several games were installed on the table. In the next setting a table was used to support bio-diversity researchers with a flora and fauna browser application. The third setting was a table on a three-day conference, NextFest 2004. Several games were installed at this table. The last setting was a two-day symposium, organized by the National GeoSpatial Agency. A map application was installed. All of the tables were observed and some usage patterns were noticed. Surprising was that these patterns occurred at most or at all of the four tables, despite the varied user populations and applications.

Subjects were hesitant to touch the table at the same time. This is more true for adults than children. When users interact simultaneously, they are concerned of touching each other. Another important finding is the ambiguous touch. The table registers every touch, even unwanted ones. Pointing and accidental touches, like leaning with wrist or elbows, are seen as input. An edge around the table can help with this. Users also prefer one-finger interaction. They rarely attempt to perform gestures on tabletops. Some basic finding is the finger resolution. Peoples fingers have different sizes. Because fingers cover elements when they touch it, for menus it is desirable to display labels slightly offset. The elements should also be large enough.

Tables smaller than 107 cm diagonal cause users to frequently bump elbows and arms with each other while interacting. Also the zooming of objects can be a problem, because it can overlap other items. Text input is another challenging point. Virtual keyboards can be used, but they are tedious. Finger-ink is not practical for large amounts of text entry, because it is difficult for people to write small with their fingers. The last finding was about mental models. Users do not view the table as a computer. They find a tabletop less intimidating and more playful than a traditional desktop environment.

Epps et al. [9] researched user preferences for tabletop gesture interaction. On a large, rear-projected horizontal screen a static image was displayed. To find out which gestures users prefer, subjects were asked to perform a specific action on one or more of the objects displayed in the image. Requested actions were for example selecting, moving, opening, rotating, scrolling or zooming. Findings were that the index finger was by far the most used hand shape. A flat hand with fingers apart, a flat hand with fingers together, grabbing/releasing and a vertical hand shape were used commonly.

In Rick et al. [48] one very interesting observation was made. Children, even older ones, lift their fingers while they drag digital objects. The table can see this as a release action and drop the objects in the wrong place. Children can easily recover from these mistakes, but it can be frustrating.

3.1.1 Guidelines for the quest

Concluded from the literature discussed above, the following multi-touch table (MT) guidelines are used for the quest.

- MT1: Give users a private workspace in front of them.
- MT2: Place global items in the center of the table.
- MT3: Do not require children to drag items over a long distance, without the option to let them lift their fingers.
- MT4: Make clear that the table can be used simultaneously.
- MT5: Use a physical border around the table, so that users can lean without touching. For tables without physical border, be careful with using the edges of the table.
- MT6: Take accidental touches into account. An accidental touch should not have a lasting effect.
- MT7: Make items suitable for different sizes fingers.
- MT8: Support users in orientation, but give them the opportunity to override.
- MT9: Make everything suitable for interaction with a single finger, and for interaction with multiple fingers.
- MT10: For important group decisions, use a central voting mechanism.

These guidelines should help the user to interact in a natural way with the multi-touch table.

3.2 Prototype

With the multi-touch guideline and the theoretical framework the initial idea of the collaborative quest was fine-tuned and a first prototype was developed. The prototype was developed for use in the experiment.

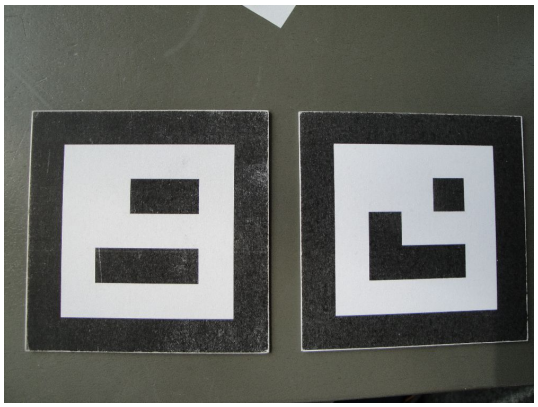
3.2.1 Hardware

The multi-touch table that has been used is the MultiTouch Cell 46" from the company MultiTouch Ltd, located in Finland. The MultiTouch Cell has an 46 inch (117 cm) TFT Display, with a resolution of 1920 by 1080 pixels and an active area of 1017 mm by 573 mm. The table itself measures 1052 mm (width) by 605 mm (height) by 630 mm (depth). The table was placed on a wooden frame of circa 20 cm high, which positioned the screen circa 80 cm above the ground. The table can recognize markers with a minimum size of 90 mm by 90 mm.

The terminals in the museum are single-touch screens placed in wooden frames. Besides the touch input, users can scan their entrance tickets using the barcode readers. The screen size of the terminal screens is 15 inch (38 cm) with a resolution of 1024 by 768 pixels.

To connect the table and terminals special markers are used, which are shown in Figure 3.1. One side of the marker contains a 2d barcode which can be recognized by the table. The other side contains a standard barcode, that can be scanned by the terminals barcode scanners.

(a) Barcode for terminal.



(b) 2D barcode for table.

Figure 3.1: The markers.

3.2.2 Software

The software developed for the quest consists of two parts. The software for the multi-touch table and the software for the terminals. The two are connected via a central database that can be reached using web services.

3.2.2.1 Terminal

The terminal software is developed by Atos Origin. It is written in HTML, JavaScript and CSS. When users scan their entrance ticket and they have started the quest at the table, the first Collaborative Quest screen is displayed, as in Figure 3.2. The screen gives an explanation of the quest and some tips. The top bar is always visible. With the close button in the right upper corner the user can close the current screen. The terminal then returns to the standard welcome screen. If the user does not touch the screen for a while, the terminal automatically returns to the welcome screen.

Next is the question screen, shown in Figure 3.3. The prototype uses five question types. Example questions can be found in Appendix D.

1. *Multiple choice.* The user must pick one answer from multiple options.
2. *Multiple response.* The user must select one or more correct answers from multiple options.
3. *Sort object order.* The user must arrange the elements in the correct order.
4. *Point & click.* The user must touch the correct part of an image.
5. *Match.* The elements at the right side on the screen must be dragged to the corresponding labels at the left side on the screen.

Figure 3.2: Terminal with welcome screen.

An optional small introduction is given, followed by the question. Below the question the answer options are displayed. At the right side of the question an image related to the question is shown. If the image does not make clear where to find the answer in the exhibition, an additional help button below the image is displayed. When the user touches the help button, the exhibit where the answer can be found is shown. The bottom of the screen contains several interface elements. First the individual score and the group score. Next a progress bar, which consists of a bar for each question. When a question has been answered, the bar becomes orange. A question cannot be answered immediately, so the user is encouraged to explore the museum to find the answer. After a rescan the question can be answered. When the answer is incorrect, the selected option becomes orange. If it is correct, it becomes green and some extra background information about the subject is shown. After three incorrect attempts, the correct answer is given.

Next is the item screen, displayed in Figure 3.4. After each question the user has to pick one item out of three. All items are related to the question and the exhibit. The items are used to connect the question with the final game. Below each item a description about the item can be found. The last terminal screen tells the user he or she finished the quest and should return to the table. If some of the other group members are not finished yet, a suggestion is also given that they could possibly be helped.

3.2.2.2 Multi-touch table

The software for the table is written in Java. It uses the open source multi-touch Java framework Multitouch for Java (MT4j) [27]. In Figure 3.5 the structure of the multi-touch table software is shown. The software consists of several scenes. Two screens are available without logging in. One is the start screen, where a group can be formed. In the other screen users can select a language. It is not possible to switch the language once a new game has been started.

Select language The language screen is one of the screens that is available to all users. The main goal is selecting the language. This can be done by touching one of the flags. After that the program returns to the group screen. Because the language screen is one of the two screens that users see when they arrive at the table, the screen shows the possibilities of a multi-touch table. When users touch the

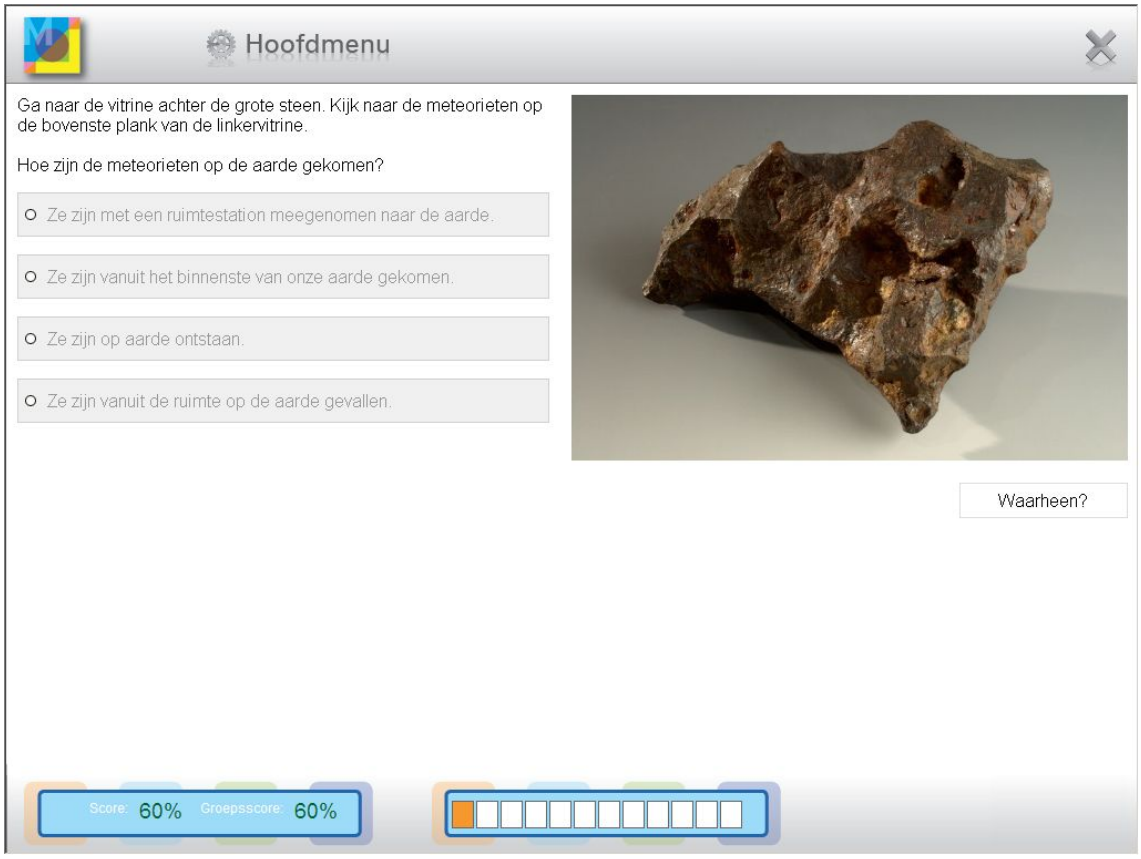


Figure 3.3: Terminal screen with a question.

table, direct feedback is given in the form of a painting. Each finger serves as a paint brush and all users can paint with as many fingers as they want. This way of interaction should be fun and should make the user aware of the fact that they can touch the table simultaneous. An example of the language screen can be seen in Figure 3.6.

Group scene The group screen is the start of the collaborative quest. In Figure 3.7 a screenshot of the scene is shown. Users can form a group. A person has to put his marker on one of the four ticket places, each in the middle of a table edge. When a marker is placed, a slider appears. The knot of the slider can be moved to the circle in the center. The knot and part of the circle turn green, this way the user can see that he has joined the quest. By pressing the button in the middle of the center circle the group can confirm that it is complete. This is done to deal with accidental touches and to let every group member have a share in the decision process to start the quest.

After the users have logged in, four scenarios are possible. If none of the group members are in a quest, a new quest is started and a screen is shown with an explanation of the quest. If all group members are finished, the group is redirected to the final game. It is also possible that not all group members are finished with the middle part of the quest. A warning is shown that some group members are still busy and might need some help. The last scenario is that the group is incorrect. This can be the case when only three of the four existing group members log in. Or when users of different groups log in, trying to create a new group when the old groups not have finished their quest. A warning will be displayed.

Similar to the language scene, feedback is given on every touch at the table. When the table is touched, a particle effect with a glow is shown. Again to make it fun and to show that simultaneous interaction is possible.

Explanation scene When a new quest is started, the first screen the users see is a screen with a general explanation of the quest. This screen is shown in Figure 3.8. This is done to let the users know

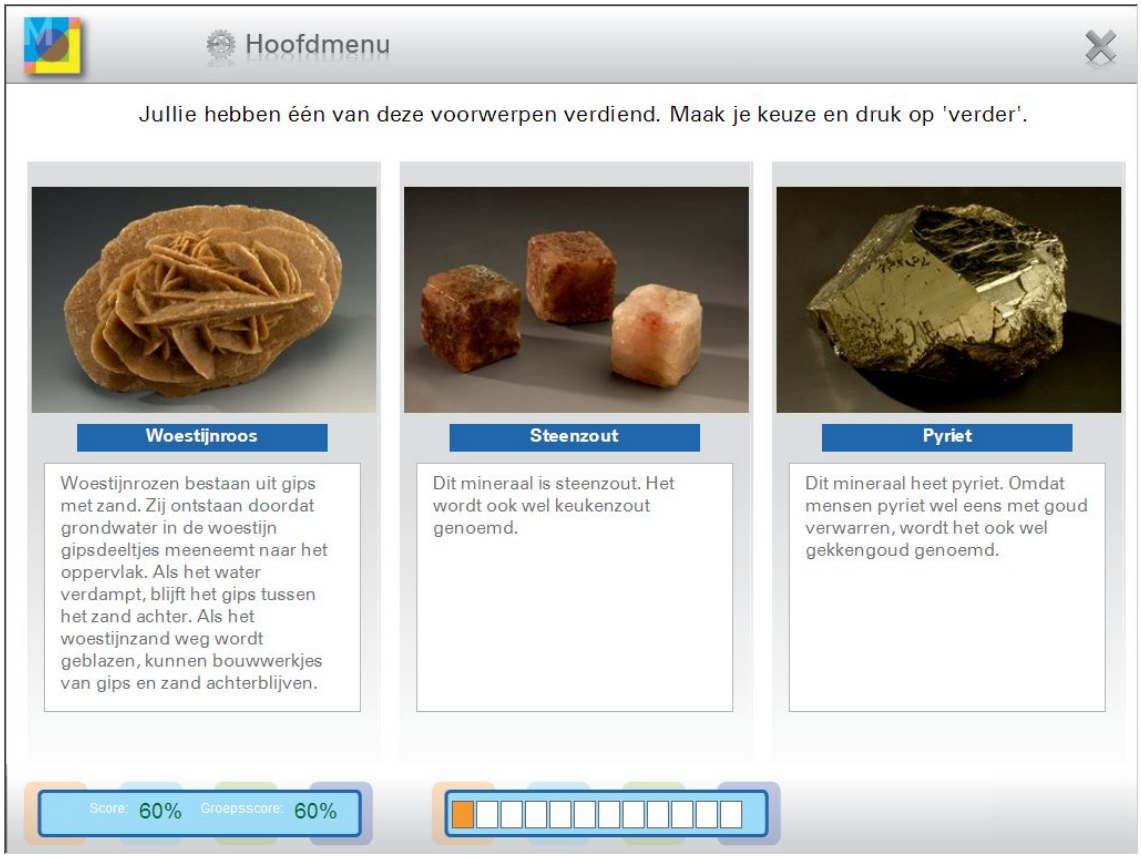


Figure 3.4: Terminal item choice screen.

what they can expect from the quest. The explanation is displayed on a virtual page in the middle of the screen. This page can be resized by placing two fingers on it and move them towards or away from each other. The page can also be rotated. This can be done by placing two fingers on the page and make a rotating movement. A book icon is placed next to each marker. When this icon is touched, the page with the explanation is automatically rotated towards the corresponding marker. To stimulate the collaboration, only one page with an explanatory text is used. Users need each other because the text is not readable from all sides of the table. By pressing a green arrow, the group can proceed to the next screen, where they can write their names.

Account scene To make the quest more personal, users have to write their names on a Scrabble-like screen. Figure 3.9 shows this screen. The names are used to link the marker to an account in the MuseOnline system, the system that is running on the terminals. Without a personal account it is not possible to get personal content at the terminals, like the quest. Stacks of letters are placed in the middle of the screen. The user can drag a letter to his personal rack. By repeating this, a name can be written. When the user has finished his or her name, he or she can confirm that by using the slider. When all users have confirmed that they are finished, the system proceeds to the preferences screen.

Preferences scene The preferences scene is an important screen. Users can select items that determine their route through the museum. These items are displayed as circles with an image inside them, as can be seen in Figure 3.10. Each item is duplicated for the amount of users, so that each user can pick the same item. Six item slots are located around the marker. Users can drag the items in those slots to select them. When all six slots are filled, they can confirm that they are finished by dragging the slider. If all users have confirmed that they are finished, a screen with an explanation of the middle part of the quest is shown.

The items on the table are linked to questions. Some explanation about the structure of the exhi-

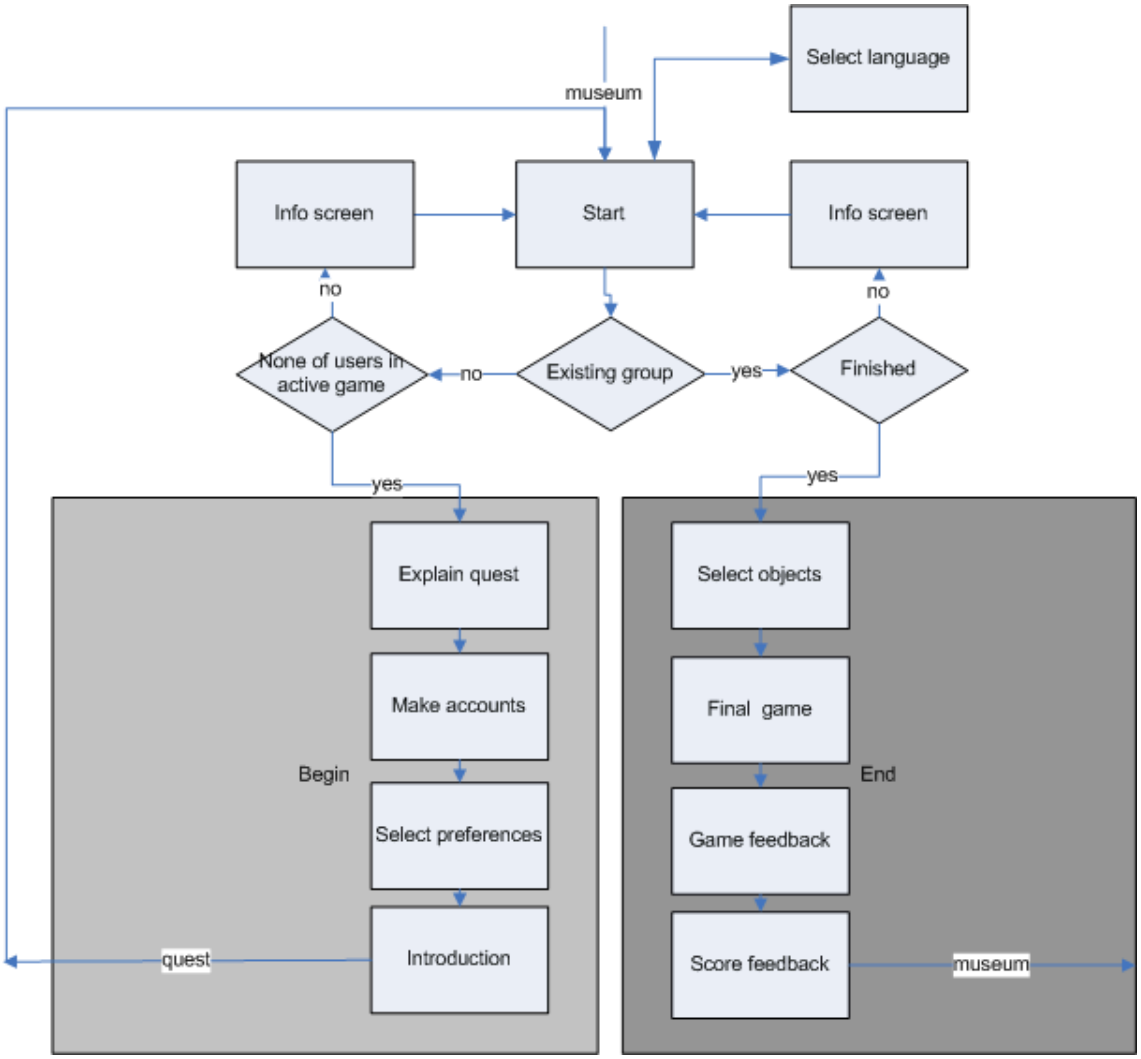


Figure 3.5: Structure of multi-touch software.

bition My World, Your World is necessary. The exhibition consists of exhibits. For the prototype and experiment, 26 of the 42 exhibits were available. For each exhibit at least four questions for the middle part are available. When users visit the same exhibit, they always get different questions about the exhibit. Because there are a lot of exhibits and each item on the table is duplicated for the amount of users, there is not enough space to map the exhibits one on one to the items. To solve this, the exhibits are divided in categories. My World, Your World is originally divided in eight zones: Stone, Bones, Sea, Human, Sun, Battle, Religion and Art. For the table a minimum of twelve categories is required. A user has to choose six items (which represents categories) and at least six other items should be available for the inverse condition. This means that the zones cannot be used. With the help of Museon employees a new division is made. The available exhibits were taken as the base. The goal was to assign the exhibits to at least twelve categories. The following criteria were used.

- All parts of the exhibition are represented, except some of the rooms that were not in the experiment.
- Every category contains at least two categories. This satisfies that when a user picks six items, twelve related exhibits are available.
- The meaning of a category is clear to the user. Even for children.
- Each category can be represented by a single image. A user should know what he or she can expect

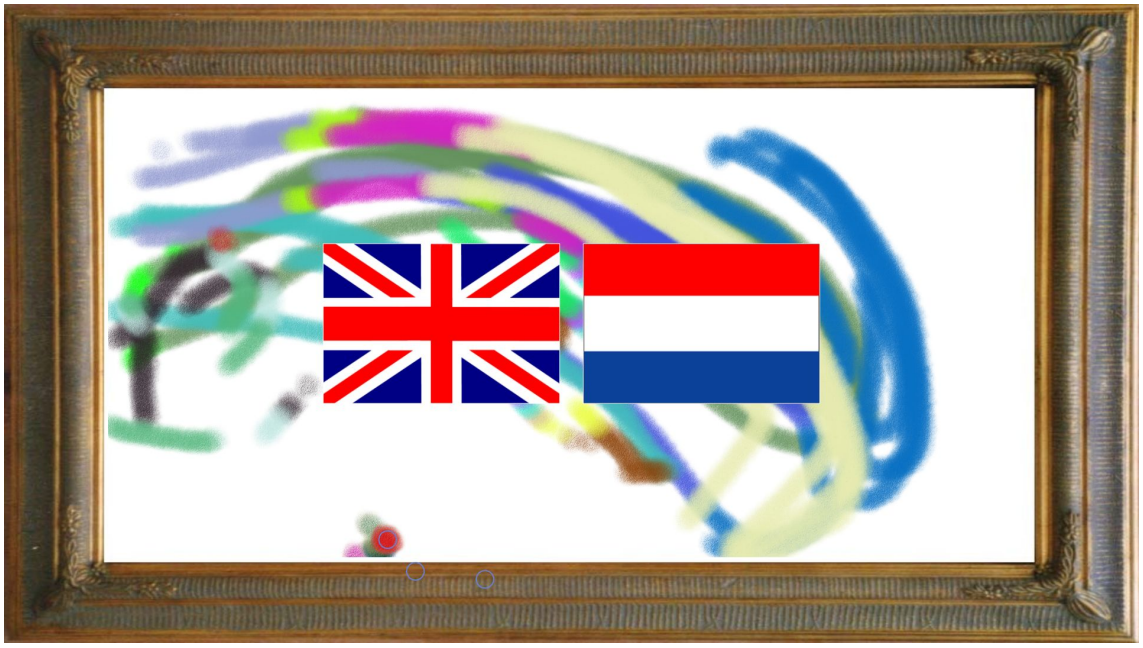


Figure 3.6: Multi-touch table language select screen.

when he or she sees an image of the category.

With these criteria the exhibits were divided in categories. When the categories were too specific or too global, the procedure was carried out again, till at least twelve, clear categories remained. The categories used were Stones, In the water, On land, In the air, Sea, Prehistory, History, Energy, Religion, Art, Water and Climate. In Appendix F an overview is given of which exhibits and categories were related. Table 3.1 shows the images that represent the categories. Descriptions are given for the categories, because it is hard to cover the content of a category in just a single title.

So the user selects six of the twelve categories. For each selected category two corresponding exhibits are selected, and from each exhibit a question is selected. This results in twelve questions for an user. The questions are ordered according to the structure of the exhibition. This is done to avoid that the users have to go criss-cross through the museum.

Like the language and group screen, the scene shows something fun at every touch. In this scene colored, moving lines are displayed after touching an empty space.

Introduction scene In Figure 3.11 a screenshot of the explanation for the middle part is shown. The explanation tells the users that they have selected twelve items that they found interesting and that each get twelve questions about those items. The users are told where to go next and encouraged to get a high score. At last a reminder is given that they can work together.

In this scene another way of presenting text is tested. Instead of one page containing the text, each user gets a page with the explanation. To make it a little bit personal, the text starts with the name of the user.

Select items When all users have finished the middle part, they can scan their markers at the group scene. When this is done, they are redirected to the select item screen, which is shown in Figure 3.12. During the quest, the users have collected twelve personal items each. For the final game they have to pick twelve items in total. The items are grouped in boxes of three or four items, according to the amount of players. There are twelve boxes in total, and from each box one item must be picked. This can be done by touching an item. The selected item gets a green border and the other items in the box become red.

When there are three users, for each user the twelve personal items are divided on four distinct boxes. This guarantees that in the final game, for each users four familiar items are present. Each user has to

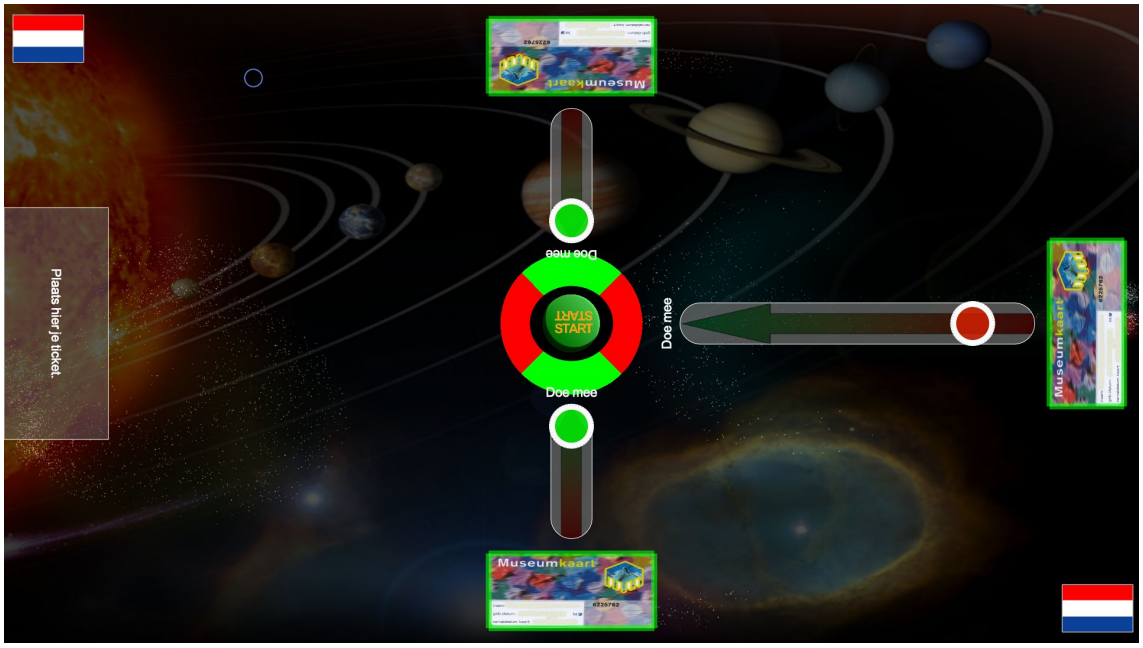


Figure 3.7: Multi-touch table group screen.

contribute to the final game to get a good result. For a group of four players, there are three boxes for each person.

After all boxes have a selected item, two sliders appear. This sliders can be used to start the final game.

Final game The final game is used to test the gained knowledge of the users. In the middle of the screen the twelve selected items from the select item scene are placed. Around these items twelve boxes with keywords can be found. From each item a unique related keyword is placed on one of the boxes. The idea of the final game is that users drag a line from a keyword to a related item. The items and keywords can be found in Appendix E. This way they create a simple mind map of items from the exhibition. For each correct connection the group earns two points, but for each incorrect connection they lose one point. And a connection cannot be removed, so users have to be careful before they make a connection. The game has a time limit of 120 seconds. Not every user has seen all the items in the museum, so cooperation is necessary. A screenshot of the final game can be found in Figure 3.13.

Game feedback After the 120 seconds, the connections are checked. This is done by an animation. Each item is selected one by one. Next all connections from the item are highlighted. A good connection turns green, an incorrect one becomes red. This is shown in Figure 3.14. The connection check animations are shown to give the users feedback on their work. They can see what they have done correct and what incorrect. This should help in the learning process.

At last the final score of the quest is given. The group is congratulated and the final game score, the amount of correct connections, the amount of incorrect connections and the total quest score are shown.

3.2.3 Limitations

The prototype has some limitations. These are hardware related. The multi-touch table is quite sensitive, but has sometimes difficulties in recognizing fingertips. Also the marker detection is not 100 percent stable. The terminal screens in the exhibition are from the resistive type. This means that they work with pressure and need actually be pressed instead of touched. It is only a light press, but it is different from the multi-touch table. This is not a problem itself, but several terminals are less sensitive and users have to press harder to see something happen. Also the barcode scanners differ. Some are older and it is harder to scan the barcode at those scanners.

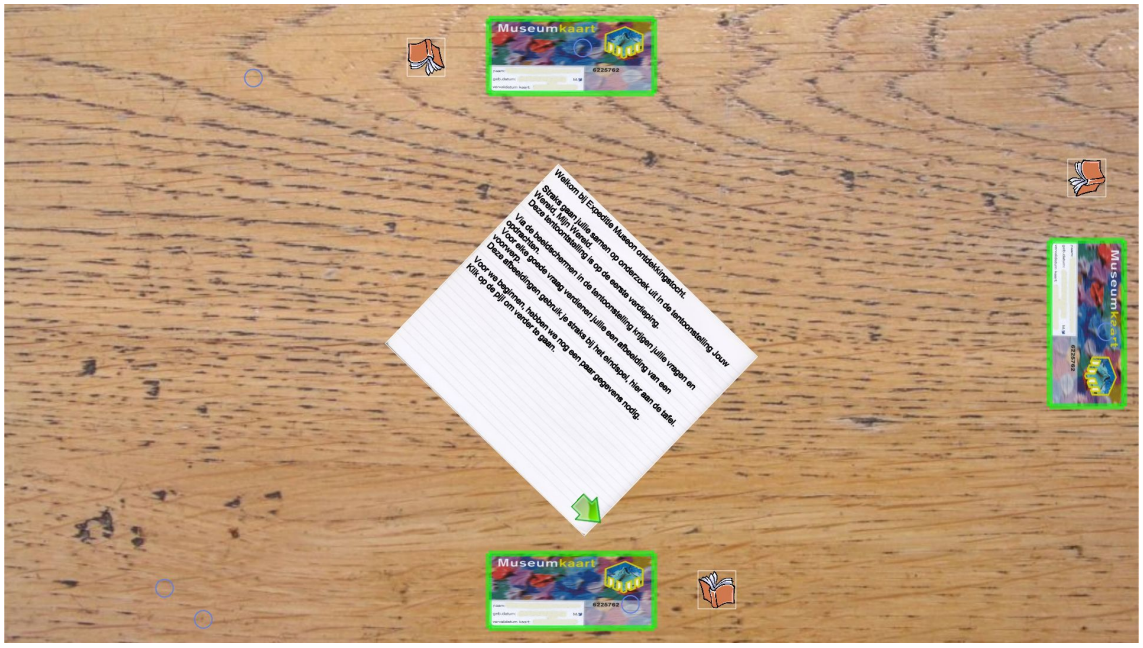


Figure 3.8: Multi-touch table explain screen.

3.3 Multi-touch guidelines in the quest

An overview of multi-touch guidelines is given in Section 3.1. Section 3.2 describes the prototype. This section concludes the chapter by linking the guidelines to the prototype.

MT1: Give users a private workspace in front of them.
The boxes for the tickets are located in the middle of each of the four edges of the table, as can be seen in Figure 3.7. This way each user is restricted to take place at one of those positions. Private user interface elements, for example the name boxes in the account scene, are placed around the ticket boxes. This and the physical distances between the users create private workspaces.

MT2: Place global items in the center of the table.
In several scenes shared elements are used. In the account scene the letters are shared and in the preference and final game scene the items are shared. All these items are located in the center of the table. The letters in the account scene are placed at fixed locations, so they will stay in the center of the table. The items in the preference scene collide with each other, which causes them to move freely around the table. This should not be a problem because each item has enough instances for all users. In the final game the items are located in the center of the table. Users can drag them, but an invisible border prevents them to drag items to the edges. In the group scene the button to start the game can be found at the middle of the table. This button affects all the users, because it confirms the group decision to start a game. Finally the virtual pages used for explanation are initially in the middle, because the explanation affects all.

MT3: Do not require children to drag items over a long distance, without the option to let them lift their fingers.
In most scenes items can be dragged. When a finger is lifted during the drag, the item stays at its current location. User can again touch the item and continue dragging. So lifting fingers does not mind in most cases. The exception is the final game scene. Users have to drag lines between keywords and items. When a finger is lifted, the line disappears and the user has to start over. This problem is solved by making the items movable. A user can drag an item towards the keyword, reducing the distance between the item and the keyword and making the line dragging easier.

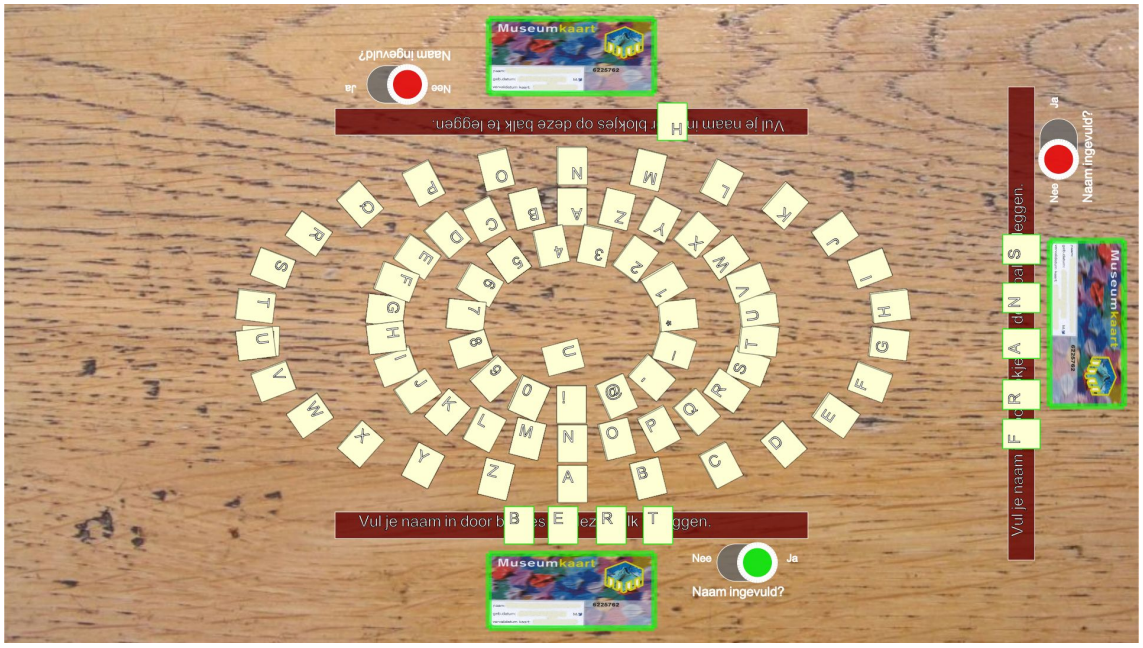


Figure 3.9: Multi-touch table account screen.

MT4: Make clear that the table can be used simultaneously.
This point is important at the two start screens, the language select scene and the group scene. When users arrive at the table, only these two screens are available. At these screens the table gives visible feedback at every touch. Users can see that it is possible to interact simultaneously. At the group scene the user is instructed to place the ticket in the ticket box. When this is done, a slider appears that has to be dragged towards the center to join the game. This is done for every single user, so if they follow their own instructions, they find out that they can drag the slider at the same time.

MT5: Use a physical border around the table, so that users can lean without touching. For tables without physical border, be careful with using the edges of the table.
The table did not have a physical border. To cover for this, buttons were not placed near the edges, as is recommended in the guideline.

MT6: Take accidental touches into account. An accidental touch should not have a lasting effect.
Accidental touches are only annoying if the result of the touch cannot be undone. The prototype consists of several sequential scenes. Once a scene is finished, users cannot return to it. To make sure that a scene is not closed by an accidental touch, sliders are used. All individual users have to switch a slider to go to the next scene. Switching a slider is almost impossible by accident and to go to the next scene all the sliders have to be switched. This confirmation mechanism reduces the influence of accidental touches. Inside the scenes nothing has a lasting effect before confirmation. So an accidental touch can be undone. The final game is an exception. Once a line is drawn, it cannot be removed.

MT7: Make items suitable for different sizes fingers.
This requirement is simply covered by making the items big enough.

MT8: Support users in orientation, but give them to opportunity to override.
In two scenes automatic orientation is used. In the account scene letters are automatically rotated towards the edge once they are placed at the personal racks. This makes it easier for the user to read the name they are writing. The orientation cannot be override by the user, because letters should not be placed in another orientation onto the rack. The same is true for the preference scene, but this time for the items instead of the letters. At the explanation scenes, the virtual paper containing the explanation

Category	Image	Description
Stones		Different types of minerals
In the water		Fossils showing the origin of life in the oceans and the evolution of to life on land
On land		Animals from dinosaurs to mammals
In the air		Collection of stuffed birds
Sea		Collection of sea life and mangroves.
Prehistory		The evolution of man.

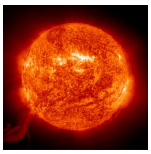
Category	Image	Description
History		Domestication and archaeology.
Energy		Several kinds of energy
Religion		Religions
Art		Creative man: art and music
Water		Facts about water and water as mineral.
Climate		Climate and influence of human on climate.

Table 3.1: Categories

can be rotated by pressing a button near the ticket box. The paper is then automatically rotated towards the user. This can be undone by grabbing the paper and rotating it by hand, using a gesture.

MT9: Make everything suitable for interaction with a single finger, and for interaction with multiple fingers.
The MT4j framework handles touches with one or two fingers. The only case that this can be problematic is when the framework thinks that a rotate or scale gesture is applied. It is hard to deal with this, because both the gestures as the two finger interaction should be possible. To deal with it, maximum and minimum sizes for scaling have been applied. So when a gesture is applied, the result is not harmful and can always be undone. Users have to find out by interacting with the table which interaction mechanisms will work and which will not.

MT10: For important group decisions, use a central voting mechanism.
The scene switches are important, because they cannot be undone and influence the whole group. At the start scene users can drag their sliders to confirm their participation. If at least three users indicate that they want to join the game, a button appears. When the button is pressed, the group has to confirm the group size to go to the next scene. This scene is followed by two individual scenes, the

Figure 3.10: Multi-touch table preference screen.

account and preference scene. After the users are finished, they have to switch a slider. When the last slider is switched, the next scene is shown. The item selection scene is different. This is a scene where collaboration is important. To stimulate that, to sliders are placed in the center of the table. Both sliders have to be switched to proceed.

This is how the requirements are implemented in the prototype. With the developed prototype, an experiment is conducted. The method for this experiment is described in the next chapter.

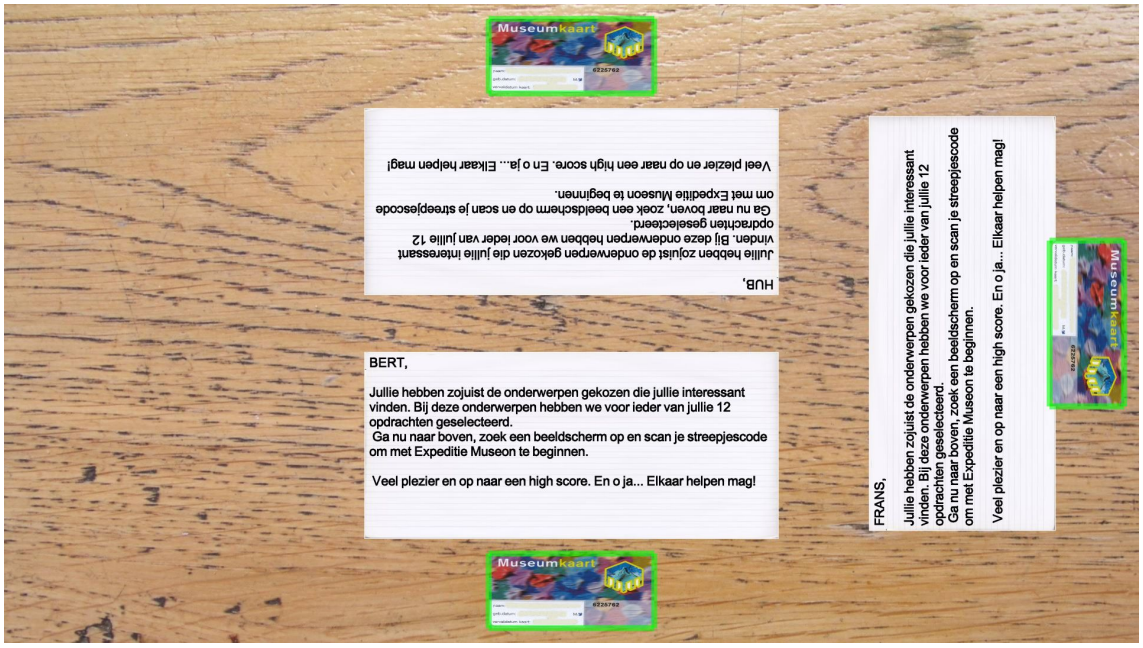


Figure 3.11: Multi-touch table introduction screen.

Figure 3.12: Multi-touch table select item screen.

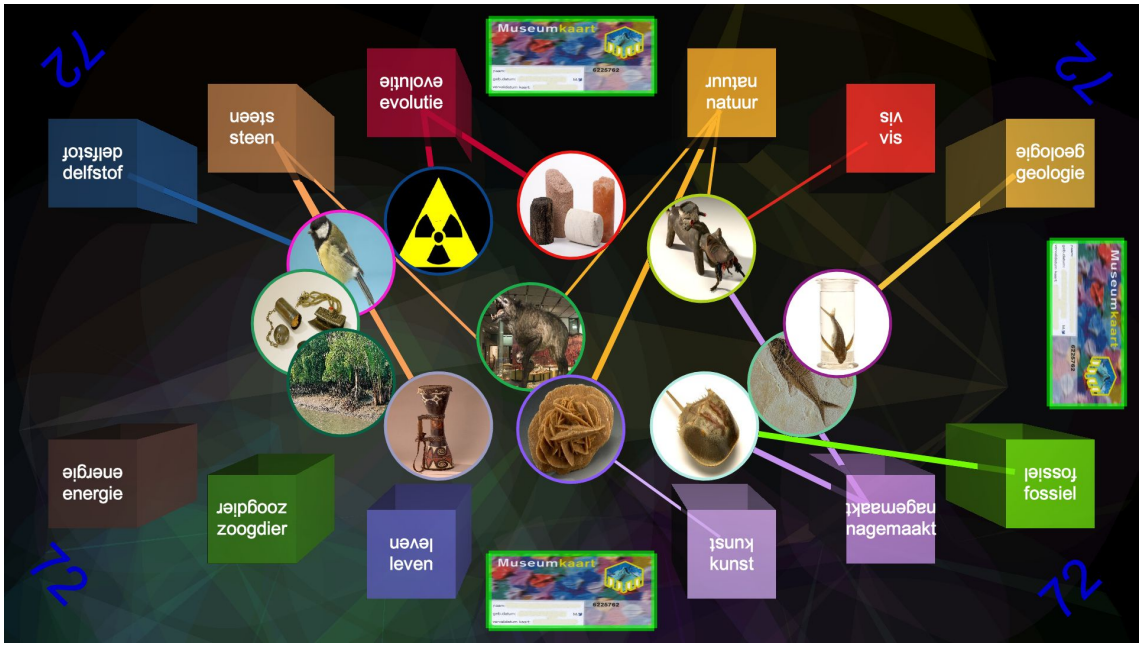


Figure 3.13: Multi-touch table final game screen.

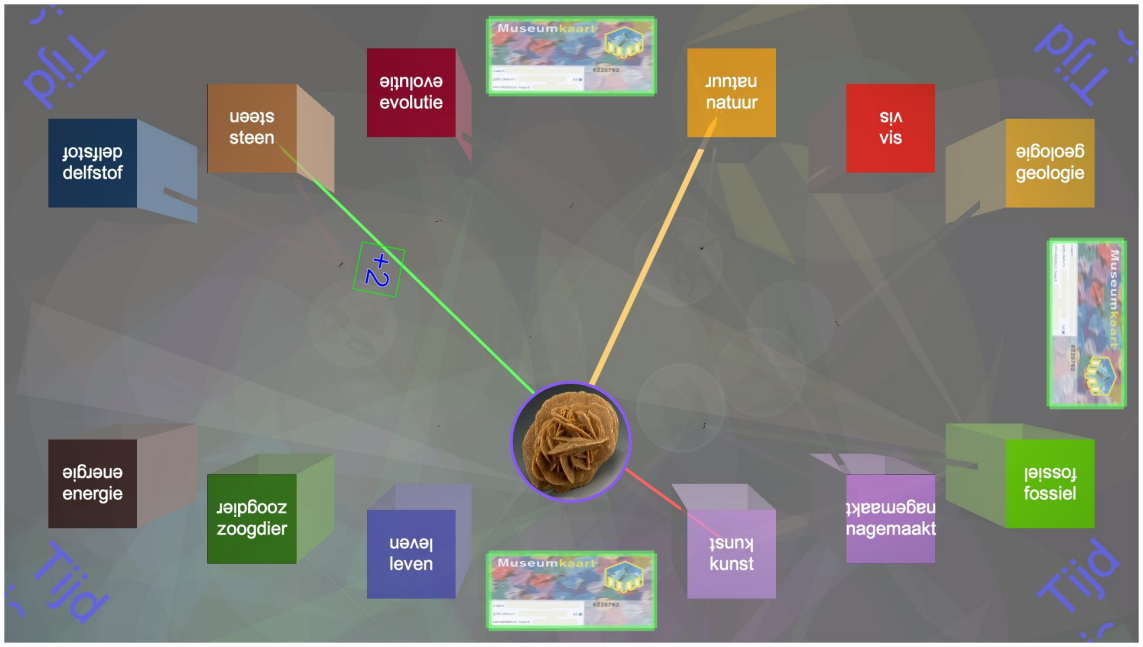


Figure 3.14: Multi-touch table final game feedback screen.

Chapter 4

Experimental method

An experiment was conducted to find answers to the research questions. The prototype described in Chapter 3 was used. Two conditions were examined. One condition that took user preferences into account (the normal condition) and one that explicitly did not (the inverse condition). Section 4.2 tells more about the conditions. This chapter describes the methodology used for this experiment.

4.1 Procedure

The experiment took place at Museon in The Hague, the Netherlands. Participants were recruited by asking visitors if they wanted to help in a test for a new exhibit. Only groups with at least two children and at least three people in total were asked to participate. They were informed about the compensation, free tickets for Museon, beforehand. The groups were randomly assigned to one of the two conditions.

The experiment started at the table. Groups got an explanation about the procedure of the experiment. They were told that a new, interactive quest was developed which started at the table, then proceeded with the question answer part and finally returned at the table for an end game. They were also told that they could help each other, could ask for help if something was not clear, and that it was still a prototype, with possible bugs. If the group wanted to participate after the explanation, they had to sign a consent form to give permission for the video recording. The consent form can be found in Appendix B. Next another small explanation was given. The group was told that they could start and that their goal was to do their best, have fun and get a high score. It was also mentioned that they could collaborate if they wanted.

During the experiment an observer was present at the table parts. The middle part was fully observed for the first three groups and partially for the other groups. At the start of the middle part all groups were observed, to check if there were no problems with the terminals and the barcode scanners. After the experiment the participants had to fill out the questionnaire. They were told that they could ask for help if they did not understand the questions. After the questionnaire the free tickets were given and the group was thanked for its participation.

The duration of a single experiment was around the two hours. The experiment was kept over a period of ten days, with one or two groups a day.

4.2 Experimental conditions

Two different conditions were used in the experiment. The conditions differ in the personal interest aspect. Users had to pick six out of twelve categories to indicate their preferences. The six selected categories represented twelve exhibits. The generated route consisted of twelve questions related to those exhibits. The first condition, called the normal condition, used the selected items to generate the route through the exhibition.

The other condition, called the inverse condition, did exactly the opposite. Again users had to pick six categories. Not the six selected categories were used to generate the route, but the remaining six. These are the categories the user was expected to be least interested in.

	Education	Enjoyment	Collaboration	Personal interest
Questionnaire	✓	✓		✓
Data logs	✓			
Video recording			✓	
Observation			✓	

Table 4.1: Measures

4.3 Participants

68 participants participated in the experiment. Ten participants were dropped because they did not finish the experiment, leaving a total of 58 participants. These participants were randomly assigned to the two conditions. Each condition had a total of eight groups. A group consisted of three or four people, with at least two children. Because the research's focus is on children, the adults are left out of the analysis. Without the adults, 36 participants remain. All children were Dutch speaking.

4.4 Measures

A questionnaire, data logs, video recording and observation are used as measures. The constructs measured were education, enjoyment, collaboration and personal interest. Subscales for the constructs were inserted in the questionnaire. An overview of how the different constructs were measured, can be found in Table 4.1. Everything at the multi-touch table was recorded on video, with permission from the participants. The video camera was located above the table, creating a top view. Sound was included. Figure 4.3 shows part of a capture from the video. The complete questionnaire can be found in Appendix A.

4.4.1 Education

Donald [8] discusses the subject of measuring learning in the museum. She treats several measures of learning. Her final conclusion is that a visit to a museum could be expected to result in learning. The time a user stays at an exhibit divided by the minimum time necessary to see and read an exhibit, this is called Holding Power, is one of the most frequently used measures by museum evaluators. But it can only be linked to learning, it is not a direct cause of learning. It is better to measure knowledge gain. This can be measured by taking tests before and after the experience. It is not always possible to take pre- and post-tests in museums and a pre-test can influence the experiment. The fact that every participant has a personal route that is determined during the quest, makes it hard to test that knowledge beforehand. So it was decided to take only a post-test, which was included in the questionnaire.

Two types of knowledge understanding were measured, *remembering* and *understanding* from the new version of Bloom's Taxonomy. These concepts are explained in Section 2.1. The remembrance of two different types of information was measured for *remembering*. The first type of information was the information directly related to the questions in the middle part, referred to as *remembering-Questions*. To measure this in the middle part the answers of the users were logged. A user had three attempts to answer each question. When the last attempt was wrong, a score of four points was given to that question, otherwise the amount of attempts was used. The total of attempts of all twelve questions was used as the test score for the question answer part. A lower score is better. The score was also visible to the user, but instead of the total attempts, the score was converted to a score between 0 and 100. A group score, the average score of all group members, was also shown. However, this score was not used as measure, but was used as a way to stimulate collaboration.

The other type of information was information related to the exhibit where the answer could be found. The measure used for this measured if participants only looked for the answers to their questions, or that they explored the exhibitions further and also remembered the other information. This type of information will be referred to as *remembering-Exhibits*. To measure it the post-test contained four multiple choice questions. This were new questions about the twelve exhibits the participants had visited.

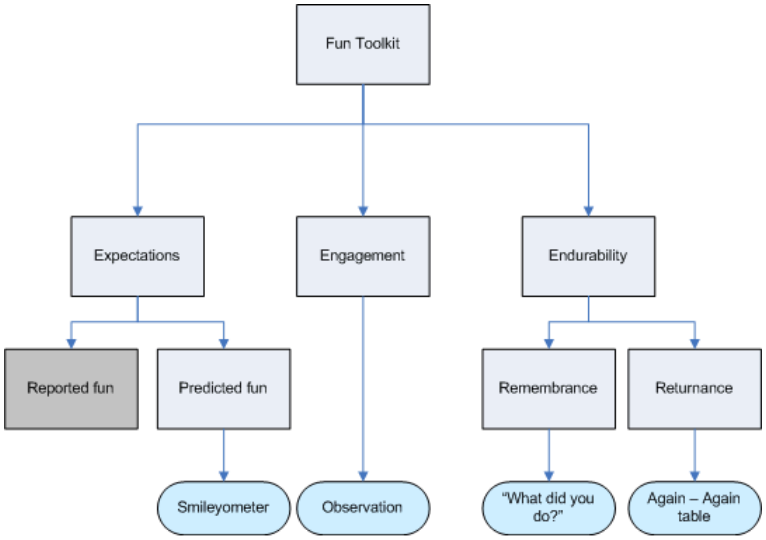


Figure 4.1: Fun toolkit.

Understanding was measured at the end game. Users had to make connections between keywords and items. The amount of good and wrong connections were used as scores to indicate how well the final game was made. The amount of good and wrong connections were assigned to each individual group member.

Besides these three measures for education it was observed if participants searched for the answers or just guessed the answers.

4.4.2 Enjoyment

Enjoyment was measured in three different ways. The first one is based on the fun toolkit for children from Read and MacFarlane [43]. According to Read and MacFarlane fun can be considered to have three dimensions. Those dimensions are expectations, engagement and endurability. The fun toolkit has tools for each of the dimensions. An overview is given in Picture 4.1. The first dimension, expectations, consists of the aspects reported fun and predicted fun. Predicted fun has not been measured for this experiment. Reported fun for the three main parts of the quest was measured using the Smileyometer. The Smileyometer is based on a 5-point Likert scale and uses five smileys, especially designed for children. The left most smiley represents awful, the right most brilliant. Picture 4.2a shows an example of the Smileyometer. Engagement, the second dimension, which should be measured by observation according Read and MacFarlane [43], was not measured in the experiment. The last dimension, endurability, consists of two facets, remembrance and returnance. The first one tells that people remember things that they have enjoyed. This can be measured by asking an open question like "what did you do?". This question is asked in the questionnaire. The other one means that people like to do fun things again. The tool Again - Again table, shown in Figure 4.2b, has been used to measure this. In the Again - Again table a child can tick if they want to do, might want to do or do not want to do an activity again.

The second way to measure enjoyment used the Intrinsic Motivation Inventory (IMI) [39], a multidimensional measurement device which can be modified to fit specific activities. For this experiment six questions from the interest/enjoyment subscale are used. All the questions used a 7-point Likert scale.

The last way to measure enjoyment were two open questions. The first one was about what the participants did like, and the other one about what they did not like.

4.4.3 Collaboration

To measure the collaboration, observation was used as a qualitative measure. Collaboration was observed at the table and in the middle part. In the middle part of the quest, the first three groups were observed extensively. Two groups with the normal condition and one group with the inverse condition. It was not possible to observe all the groups. Two more groups with the inverse condition were less extensively

(a) The Smileyometer.

Would you like to do it Again?

	Yes	Maybe	No
Museon quest	✓		

(b) The Again - Again table.

Figure 4.2: Two tools of the fun toolkit.

observed to check if the collaboration was the same as for the earlier observed groups. Special attention was given to several points.

- Did group members go their own way, or did they stay together?
- Did group members help each other in answering the questions?
- When a user finished the question-answer part before his or her teammates, what did the user do?

At the table the collaboration was also observed. Did users help each other with the interaction and explanations of the scenes?

4.4.4 Personal interest

Three questions were asked to measure personal interest. The questions were on a 7-point Likert scale.

4.4.5 Demographics and guidance

Several questions were asked to define a demographic profile of the user. The demographic topics were age, gender and recent Museon and museum visits. Finally two questions were asked to measure perceived guidance. The questions were on a 7-point Likert scale.

4.5 Data analysis

For enjoyment, personal interest and guidance questions on a 7-point Likert scale were asked. The subscales for these constructs have been tested for reliability with Cronbach's alpha tests. 0.7 was used as cut-off point for Cronbach's alpha [52]. This means that an alpha of 0.7 or higher indicates that the subscale has an acceptable internal consistency. The subscales based on the Intrinsic Motivation Inventory were tested for normality with the Shapiro-Wilk test. Together with the two experimental conditions (normal and inverse) and different subjects assigned to each condition, the independent T-test was considered suitable to analyze the subscales for enjoyment, personal interest and guidance that have a normal distribution. The T-test assesses if the means of two groups are statistically different from each other. The null hypothesis is that the sample means are the same. When the T-test gives a

Figure 4.3: Capture of the video.

p-value below 0.05, then the null hypothesis is rejected and the experimental hypothesis is accepted. This means that the two sample means differ. For data that was not normally distributed, the Mann-Whitney test was considered suitable. A p-value below 0.05 for the Mann-Whitney test means also that the two samples differ.

For the Smileyometer and education measures again T-tests and Mann-Whitney tests were used. The smileys used in the Smileyometer were designed with the help of children, making sure that the scale represented the values behind the smileys. The data measured with the Again - Again table was ordinal and was analyzed with a chi-square test. The chi-square test indicates if there is a significant association between two categorical variables, but does not tell how strong that association might be. When the significance value is smaller than 0.05, the null hypothesis that the two variables are not related, can be rejected. In that case the two variables are related, what means that the two samples differ. For the open questions the answer instances were counted. After that the answers were grouped in more general categories. No tests were run on the open questions. The goal of the open questions was to explore more broadly and to find explanations for the closed questions.

The results of the experiment are given in the next chapter.

Chapter 5

Results

The experiment was done between 22 October 2010 and 7 November 2010. This chapter describes the results of the experiment. Only the data of the 36 children is used for the results in this chapter. The data of 22 adults has been analyzed, and interesting findings are mentioned. Interpretation and discussion of the data is done in Chapter 6.

5.1 Data preparation

Before the data was interpreted, data transformations have been applied. For several scale items the data was reversed, so all scale items were in the same direction. During the experiment a modification was made to the final game. As a result the data for the first version of the final game became obsolete. This data was removed.

Last of all the data was checked for outliers. A few outliers were found, but no clear cause could be found for them. So none of the outliers were removed.

5.2 Demographics

The mean age of children in the normal condition was 10.83 years old and in the inverse condition 10.11 years old. In the normal condition 50% of the children was female, in the inverse condition 33%. More detailed information about the participants can be found in Table 5.1. Both conditions had six groups containing two children and two groups containing three children. For the normal condition 78% did not visit Museon earlier in 2010. For the inverse condition this was 89%. All of the children from the normal condition visited at least once other museums in 2010. For the inverse condition this was 72%.

Regarding the demographics, Chi-square tests (Visit Museon before: $\chi^2 = 6.133$, p=0.047 ; Visit other museums before: $\chi^2 = 12.482$, p=0.014) showed that there were two significant differences between

Condition	Group	Mean (std. dev)	N
Normal condition	Child	10.83 (1.95)	18
	Adults	42.10 (6.44)	10
Inverse condition	Child	10.11 (1.94)	18
	Adults	47.67 (10.5)	12

(a) Age

	Normal	Inverse
Male	9	7
Female	9	11

(b) Gender

Table 5.1: Age and gender of the participants.

	Normal	Inverse	Total	
Energy	13	16	29	$\chi^2 = 1.596$, p=0.206
History	11	5	16	$\chi^2 = 4.050$, p=0.044
Climate	12	14	26	$\chi^2 = 0.554$, p=0.457
In the air	11	14	25	$\chi^2 = 1.178$, p=0.469
On land	9	12	21	$\chi^2 = 1.029$, p=0.310
Stones	11	9	20	$\chi^2 = 0.450$, p=0.502
Water	9	14	23	$\chi^2 = 3.010$, p=0.083
Sea	13	9	22	$\chi^2 = 1.870$, p=0.171
Art	5	5	10	$\chi^2 = 0.000$, p=1.000
In the water	9	6	15	$\chi^2 = 1.029$, p=0.310
Religion	4	3	7	$\chi^2 = 0.177$, p=0.674
Prehistory	1	1	2	$\chi^2 = 0.000$, p=1.000

Table 5.2: The selected categories at the table.

the normal and inverse condition. Participants in the normal condition had visited both Museon and other museums more frequent. With linear regression dependencies between museum visits and the other variables were checked. No significant results were found.

5.3 Personal interest

Participants had to choose items at the table, to form the routes for the question answer part. Table 5.2 shows how many times the categories are selected. The category history gives a significant difference, but overall the personal interest regarding the selected items is quite similar for both groups. This implies that the groups have similar interests and it is valid to compare the groups.

5.3.1 Normal and inverse condition

A questionnaire was used to find out if the participants found the quest interesting. The questionnaire contained a subscale to measure personal interest with three items on a 7-point Likert scale. With a Cronbach's alpha of 0.516 the subscale was unreliable. Deleting the item "*I found the objects I saw during the quest interesting*" gives a Cronbach's alpha of 0.760. In Table 5.3 the results are presented. The results for the non-reliable subscale are given because the same scale gives significant results for the adults (See 5.3.2). No significant differences were found between the two conditions for the children.

	Normal condition (std. dev)	Inverse condition	Both	Sig. (2-tailed)
Corrected Subscale Personal interest	5.78(1.56)	5.53 (1.30)	5.65 (1.42)	Z=-1.050, p=0.294
Subscale Personal interest	5.87 (1.24)	5.57 (1.02)	5.72 (1.13)	Z=-1.088, p=0.277

Table 5.3: Personal interest measured with three items using a 7-point Likert scale.

5.3.2 Adults

A significant result however is found on the adults data. With N=3 Cronbach's alpha is 0.761. After deleting the item "*I found the objects I saw during the quest interesting*" Cronbach's alpha is 0.958. Although the first subscale already was reliable, the corrected subscale is showed so it can be compared with the data for the children. Table 5.4 shows the results for the three combined items and for the two combined items. A higher score means that the participants were more satisfied with their questions and selected items. So the adults in the normal condition were more satisfied with the questions than

the participants in the inverse condition (z=-2.202, p=0.028). For both adults and children the average scores were above 5.00 (5.64 for the adults and 5.72 for the children).

	Normal condition (std. dev)	Inverse condition	Both	Sig. (2-tailed)
Corrected Subscale Personal interest	6.30 (1.23)	4.96 (1.59)	5.57 (1.56)	Z=-2.187, p=0.029
Subscale Personal interest	6.27 (1.07)	5.11 (1.30)	5.64 (1.31)	z=-2.202, p=0.028

Table 5.4: Personal interest of adults measured with three items using a 7-point Likert scale.

5.3.3 Observations

This section contains some remarks and observations about personal interest. One group with the inverse condition mentioned after the questionnaire that they had seen a lot of things in the exhibition of which also seemed interesting to them. But they saw it as an incentive to visit the exhibition again. From another group with the inverse condition the father mentioned that he found it strange that he did not get any question about the sun, of which he had selected an image at table.

At the table the participants had to select items at the preference scene. There were enough instances of the items for each participant. But despite that, participants "stole" items from each other. Once children decided that they wanted an item, they were very persevering to get it. So they selected the items they really wanted and did not choose random items, which is important because the participants had to pick the items they preferred.

5.4 Education

Education has been measured by three variables. The first was the amount of attempts for the middle part, the second was the score of the final game and the last was the test in the questionnaire. Besides these three measures it was observed if participants guessed the answers.

5.4.1 Normal and inverse condition

For the middle part, participants had to answer 12 questions. For each question they had a maximum of three attempts to answer the question. When after three attempts the correct answer still was not found, it was counted as four attempts. So the score of this part (*remembering-Questions*) ranges from 12 till 48, where 12 is the best result. Table 5.5 shows the results of the middle part. No significant differences were found between the normal and inverse condition. The average amount of attempts in the middle part was 17.86. Because a lower score is better, this seems to be a good average.

	Normal condition (std. dev)	Inverse condition	Both	Sig. (2-tailed)
Remembering-Questions	18.22 (5.77)	17.50(4.22)	17.86 (4.99)	Z=-0.433, p=0.665

Table 5.5: The attempts needed to answer the twelve questions in the middle part, measuring *remembering* from Bloom's Taxonomy.

In the final game, the participants had to make connections between items and keywords (*understanding*). The maximum possible good connections depended on the chosen items, but was between 40 and 56. The maximum possible wrong connections was between the 88 and 104. The highest score for good connections was 18 and for wrong connections five. Because the difference between the maximum possible scores and the maximum obtained scores was high, it sufficed to use the absolute values for the connections. Table 5.6 shows how many connections were made. Despite the final game was a group game, the group score was assigned to each participant as an individual score. For the final game the

scores for the good connections were around the 20-25% of the highest possible. For the wrong connections this was only around the 3%. For the amount of good connections a significant difference was found between the normal and inverse condition (t(23)=3.708, p=0.001). The groups with the normal condition scored higher than the groups with the inverse condition.

	Normal condition	Inverse condition	Both	Sig. (2-tailed)
Understanding - Good connections	12.85 (3.13)	9.17 (1.47)	11.08 (3.07)	t(23) = 3.708 p=0.001
Understanding - Wrong connections	3.08 (1.19)	2.92 (1.12)	3.00 (1.167)	Z=-0.198, p=0.843

Table 5.6: The connections made in the final game. This measures *understanding* from Bloom's Taxonomy.

A small part of the questionnaire was a test. Four multiple choice questions about the visited exhibits were asked (Remembering-Exhibits). The maximum score for the test was four, the minimum score was zero. No significant difference was found. The result is shown in Table 5.7. The scores of the education test were quite low. The average was 2 out of 4. Participants mentioned during the test that they had no idea what the answer was, because they had not seen the object in the museum. They also mentioned sometimes that they knew a question because they helped a group member with it.

	Normal condition	Inverse condition	Both	Sig. (2-tailed)
Remembering-Exhibits	1.94 (1.29)	2.06 (0.90)	2.00 (1.09)	Z=-0.433, p=0.665

Table 5.7: Results for *remembering* from Bloom's Taxonomy, measured with a test in the post-questionnaire. This was a multiple choice test with four items.

5.4.2 Observations

During the experiments some of the participants were observed. It showed that the children were really looking for the answers and not just guessing them. Only when they already knew the answer the search part was skipped. This was very clear in the following example of a mother and daughter. The daughter had already visited the exhibit, but still did not know the answer. The mother advised her to guess and just pick one of the answers. But the daughter refused, visited the exhibit again and came back with the correct answer, indicating that she really tried to answer the question.

At the final game two interesting observations were made. The first was that several participants mentioned that their gained knowledge was tested in the game. The second was the strategy for the final game. Before the game an explanation was given, in which was told that the time started after the first connection was made. Several children told their team mates to first discuss which lines they should draw, before a connection was made. That way they had more time to think.

5.5 Enjoyment

Enjoyment was measured in five different ways. The Smileyometer and the Again - Again table were used to give an indication about the fun of the three main parts of the quest. A questionnaire with a subscale based on the Intrinsic Motivation Inventory (IMI) [39] was used to get a more global overview of enjoyment. Finally open questions and observation were used to get more qualitative data.

5.5.1 Normal and inverse condition

Three questions used the Smileyometer as instrument. The results are shown in Table 5.8. The scale is a 5-point Likert scale. No significant differences between the two conditions were found.

	Normal condition	Inverse condition	Both	Sig. (2-tailed)
Enjoyment begin part	4.11 (0.83)	4.11 (0.68)	4.11 (0.75)	Z=-0.209, p=0.834
Enjoyment middle part	4.22 (0.81)	4.62 (0.70)	4.42 (0.77)	Z=-1.610, p=0.107
Enjoyment end part	4.06 (1.00)	4.17 (0.99)	4.11 (0.98)	Z=-0.389, p=0.698

Table 5.8: Enjoyment for the three main parts measured with the Smileyometer. The results are on a 5-point Likert scale.

The Again - Again table was used in three questions about the begin, middle and end part. Users could choose between no, maybe and yes on the question if they want to do an activity again. The results are shown in Table 5.9. Chi-square tests (begin: χ^2=1.091, p=0.580 ; middle: χ^2=2.974, p=0.226; end: χ^2=4.015, p=0.134) show that there were no significant differences between the two conditions for the three questions. The average Smileyometer values, which measured the enjoyment of the main parts, were for all parts above the 4.11. The value of the middle part was slightly higher (4.42). The Again - Again table did not support the higher values for the middle part, the values were quite comparable for the three parts.

		Normal condition	Inverse condition	Total
Again - Again table begin part	No	0	1	1
	Maybe	6	5	11
	Yes	12	12	24
Again - Again table middle part	No	1	2	3
	Maybe	6	2	8
	Yes	10	14	24
Again - Again table end part	No	2	0	2
	Maybe	2	6	8
	Yes	13	12	25

Table 5.9: Enjoyment measured with the Again - Again table for the three main parts.

To measure enjoyment the Intrinsic Motivation Inventory was used. The questionnaire contained a subscale for enjoyment with six items on a 7-point Likert scale. Cronbach's alpha was 0.568, which makes the subscale unreliable. Because the subscale is not reliable, all the items were analyzed individually, but none of them showed a significant difference between the two conditions. The results for the subscale are shown in Table 5.10. The average score on the subscale enjoyment was 5.96 on a 7-point Likert scale, which seemed to be quite high.

	Normal condition (std. dev)	Inverse condition	Both	Sig. (2-tailed)
Subscale Enjoyment	5.89 (0.84)	6.04 (0.87)	5.96 (0.85)	Z=-0.908, p=0.364

Table 5.10: Enjoyment measured with six items using a 7-point Likert scale.

The questionnaire contained three open questions. A question about what the participants liked, what they did not like and a question that asked them to describe what they had done.

The first question was about the things the participants liked about the quest. 27 different answers were given, out of a total of 66 answers. Two children left the question open (zero in the normal condition, two in the inverse condition). Table 5.11 shows the answers with more than one occurrence or answers that are interesting. Most participants mentioned the middle part as one of the things they did like.

Answer	Inverse	Normal	Total	Difference
Middle part	12	7	19	5
Final part	4	3	7	1
Everything	3	4	7	1
Begin part	3	3	6	0
Table	4	1	5	3
Saw a lot	0	2	2	2
Learning	1	0	1	1

Table 5.11: Answers on the open question What did you like?

Answer	Inverse	Normal	Total	Difference
Nothing	8	5	13	3
Hard/impossible to find the answers	5	2	7	3
Incorrect questions	0	2	2	2
Individual questions	2	0	2	2

Table 5.12: Answers on the open question What did you not like?

The second question was about the things the participants did not like about the quest. 16 different answers were given, out of a total of 36 answers. Four children left the question open (two in the normal condition, two in the inverse condition). Table 5.12 shows the answers with more than one occurrence or answers that are interesting. On the question "what did you not like" the most common answer was that they liked everything. Second was the answer that some answers were hard to find.

Answer	Inverse	Normal	Total	Difference
Answering questions	9	10	19	1
Information gathering	8	3	11	5
Final part	2	7	9	5
Walking around	2	3	5	1
Item selection at the table	1	3	4	2
Playing with the computer	2	1	3	1
Begin part	1	2	3	1
Reading	1	2	3	1
Saw animals	1	1	2	0
Saw small statues	0	2	2	2
Running	1	1	2	0
Doing things/experiments	0	2	2	2

Table 5.13: Answers on the open question What have you done?

Finally the participants were asked to describe what they had done. 22 different answers were given, out of a total of 74 answers. Three children left the question open (one in the normal condition, two in the inverse condition). Table 5.13 shows the answers with more than one occurrence. The remembrance question "What have you done" resulted mostly in answers about the middle part. Nineteen times participants described that they had to answer questions and eleven times that they had to gather information.

5.5.2 Adults

The Cronbach's alpha for the subscale with the six enjoyment items was 0.800. So the enjoyment subscale based on the Intrinsic Motivation Inventory was reliable for adults, but not for children. Still no significant differences were found between the two conditions (Z=-0.762, p=0.446).

5.5.3 Observations enjoyment

Children seemed to be very motivated in the middle part of the quest. They were actively looking for answers, till the last question. Two mothers mentioned that they were surprised that their children were so devoted. They were expecting that their children would not finish the quest, but they did. Even a seven year old girl was enthusiastic the whole middle part.

Disappointment was observed when the group score changed to a lower value. An eye was also kept on the individual scores by the participants. Several participants were disappointed when the score became lower than 60%.

5.6 Collaboration

Collaboration was mainly observed at the middle part, but some attention was also given to collaboration at the table. When some interesting collaboration was observed, it was written down. This results in some findings, but nothing can be said about the division over the conditions.

At the begin screen all children interacted at the same time. Sometimes a child wanted to try something and asked the others to stop interacting. By giving instructions and deliberation the child could reach the thing he had in mind. The same thing appeared in the final game. Several times one child asked the group to first think about the right connections, before starting the game. Participants collaborated also in scenes with a central explanation box. Most of the times one person read out the text. And when some group members did not know what to do, they were helped by the others. In the preference scene participants 'stole' items from each other. But when a group member told them not to do that, it was ok. Most of the time the group members explained that there were more instances of the same item.

In the middle part two groups with the normal condition and one group with the inverse condition were observed for collaboration. Two more groups with the inverse condition were observed to check if they collaborated the same way as the first group. The other groups were only partly observed. It was only checked if there was deviant behavior, which did not occur. There were also no striking differences between the two conditions. Most of the groups entered the second floor with the whole group. The first thing they did was scanning their tickets at the terminals. Smaller groups of two persons (like a father with a son or a mother with a daughter) were formed, but the two subgroups stayed around each other. The participants answered their own questions. Two parents commented afterwards that there were too many questions. They had their own twelve questions, but had also supported their children, making it a total of 24 questions. Later in the quest each group member was working individual, but returned to other group members when help was needed. At the end of the quest the group members came together again. When a group member finished earlier, he or she helped another group member or visited other parts of the museum. When some group members were in other parts of the museum, they gathered at the multi-touch table to play the final game. Interesting was the influence of the group score. Disappointment and joy were easy to observe when the group score changed.

5.7 Guidance

To measure guidance a subscale with two items on a 7-point Likert scale was used. With a Cronbach's alpha of 0.324 the subscale was unreliable. Because the subscale seemed to be measuring different constructs, the items were also analyzed individual. There were no significant differences found between the two conditions. The results are shown in Table 5.14. Participants did not feel lost (Average score of 5.56), but found it more hard to locate the exhibits where they could find the answer to the questions (average score of 4.58). The score for the construct guidance seemed to be quite high.

	Normal condition (std. dev)	Inverse condition	Both	Sig. (2-tailed)
Subscale Guidance	5.19 (1.41)	5.25 (1.76)	5.22 (1.57)	Z=-0.448, p=0.654

Table 5.14: Guidance measured with two items using a 7-point Likert scale.

5.8 Multi-touch and terminal interaction

The interaction with the multi-touch table was observed. Special attention was given to the multi-touch guidelines from section 3.1.

5.8.1 Multi-touch guidelines

This section describes the observations for some of the multi-touch guidelines.

MT1: Give users a private workspace in front of them. In the preference scene an instruction text was displayed in the center of the table and in the middle of all the edges. The actual text of the messages at the center and the messages at the edges were different, but the content was the same. None of the participants read the text in the center, but everyone read the text in front of them. This was an example of the private workspaces. In the account scene a Scrabble-like game was used for name input. Each member had a personal rack. When a letter was placed on it, none of the other users tried to get it. The whole concept was clear to the participants, even for the seven-year old.

MT2: Place global items in the center of the table. At the first instruction screen an instruction textbox was placed in the center. In most of the cases one person read the text aloud. Another variant was tested with individual instruction textboxes. Everyone started with reading their own text, but when someone was ready, they started with resizing and moving the box, making it hard for the other group members to read their text.

MT3: Do not require children to drag items over a long distance, without the option to let them lift their fingers. Young children (eight year and younger) found it hard to draw a straight, long line. This was sometimes problematic in the final game. Moving the items towards the keyword, or asking for help were solutions to this problem.

MT4: Make clear that the table can be used simultaneously. The group scene with the particles attracted a lot of children. Both children and adults liked the effects. They described it as fireworks, stars or Harry Potter. When children saw that they could create the colors by touching the screen, they immediately started to interact with the table. So simultaneous interaction seemed natural.

MT5: Use a physical border around the table, so that users can lean without touching. For tables without physical border, be careful with using the edges of the table. The table did not have a physical border. People still leaned on the edges. For the begin screen this was a problem, because the language flags were too close to the edges. Sometimes the scene switched to the language scene, because of an accidental touch. Most of the time the group found out what the cause of this problem was and instructed the person to watch out when leaning on the table.

MT6: Take accidental touches into account. An accidental touch should not have a lasting effect. The instruction screens contained buttons to go to the next scene. A few times the button was pressed before the text was read.

MT7: Make items suitable for different sizes fingers. Some people, mostly children, experienced more problems with the interaction with the table than others. Their fingers were recognized worse. Children solved the problem by making several small movements, which seemed to work better.

MT8: Support users in orientation, but give them the opportunity to override. The scene with a central instruction text supported the users in orientation. On each edge a button was placed which could rotate the text box towards that edge. Those buttons were not often used, but when they were discovered, all users started pressing them. The result was an unworkable situation. Most of the time one person was reading the text aloud. The textbox could also be rotated or scaled by touching the box with two fingers. When this was first discovered, it became again chaotic, but only for a short period.

MT9: Make everything suitable for interaction with a single finger, and for interaction with multiple fingers. The table was less sensitive near the corners. Some children tried to interact with the objects on the screen by grabbing them with the whole hand. The table software found it hard to recognize fingers in it and ignored that kind of input. This seemed to be no problem for the children. They kept trying until they succeeded.

MT10: For important group decisions, use a central voting mechanism. The slider worked good as a central voting mechanism. At the first screen some parents found it difficult what to do with the slider. Sometimes they moved the marker over the slider trail. But when they did not know what to do, other group members helped them. The markers self were not always perfectly recognized, which caused a blinking virtual box. But the users did not mind that, they interacted the same way as with non blinking boxes.

5.8.2 Terminals

The touch screens of the terminals worked on pressure. Not all the terminals responded very well, which annoyed some of the users. None of them mentioned the same problem for the table, although from observation it was clear that the table was not responding all the time. Scanning of the barcodes and the speed of the terminals were also mentioned as annoying things.

The results described in this chapter are interpreted and discussed in the next chapter.

Chapter 6

Discussion and conclusion

One of the main challenges for museums is to maintain the museum integrity as a conserving and educational institution on one hand, and make the museum more competitive and popular on the other hand. Museum visitors prefer activities that are personally relevant to them [24]. Personal relevance is also linked to education and enjoyment. This research tries to find an answer to the question if the educational and fun experience of a museum can be enhanced through personalization. An experiment was conducted to find answers to the sub questions, which were developed to address the main question. The participants in the experiment were divided over two conditions. One that took personal interest into account (normal condition) and one that did not (inverse condition). This chapter discusses the results from the experiment and concludes with an answer to the research question.

6.1 Research questions revisited

With the help of five sub questions an answer to the research question was addressed.

The first sub question investigated the influence of personalization on the enjoyment of visitors. According to hypothesis one it was expected that the reported enjoyment would be higher for the variant that takes personal interest into account than for the one that does not. Four measures were used to investigate this. The Smileyometer measured the reported fun for the three main parts. The Again - Again table indicated if participants wanted to do one of the main parts again. With the questions based on the Intrinsic Motivation Inventory reported enjoyment for the whole quest was measured. The open questions resulted in overviews of things participants liked or did not like. For none of the measures significant differences were found between the two conditions. Hypothesis one could not be confirmed, personalization caused no noticeable influence on enjoyment.

The second sub question focused on the influence of personalization on the education of museum visitors. According to hypothesis two, visitors are expected to learn more from the variant that takes personal interest into account than from the one that does not. Three measures were used to find out if the hypothesis should be accepted or rejected. The first one measured *remembering* for the twelve questions in the middle part. The second one measured *understanding* using the final game. The third measure, the post-test with four multiple choice questions, measured *remembering* for the information related to exhibits. A significant difference was found for *understanding*. Participants in the normal condition group made more good connections than participants in the inverse condition group. For the other two measures no significant differences were found. So hypothesis two is partly accepted. Regarding *understanding*, personalization has a noticeable influence on education.

The third sub question tried to find out if people collaborated during the quest. This was only measured by qualitative observations. Not all groups were observed equally, so it is hard to give a clear answer to this question. Collaboration was both observed at the table and in the middle part. When there were no shared elements on the table, participants were mostly busy with their own tasks. When there were shared elements, like a central explain box, participants helped each other and debated more. In the middle part the same behaviour was observed. Each individual group member had his own goal, answering the questions as good as possible. So the participants were looking for the answers in the exhibition, but they also helped group members with their questions during the quest. The remarks

made at the post-test with the four multiple choice questions supported this. Participants mentioned that they already had seen the questions when they were helping a group member. The responses on the group score showed that the collective goal of getting a good group score was also important to them. So the answer to this sub question is that the participants in the quest collaborated at the table and in the middle part. The participants were mostly busy with their own tasks, but always with the shared goal of getting a good group score in mind.

The fourth sub question investigated if the terminal computers and the multi-touch table were suitable to be used for a collaborative oriented guide through the museum. Participants found the terminals sometimes annoying, because the barcode scanners did not always recognize the barcodes and the touch screens of some terminals were insensitive. But despite the annoyances, the middle part, the part where the terminals were used, scored high in the enjoyment test. The terminals were easy to use, participants understood how to interact with them without any help. For the quest it was useful that the terminals were all over the exhibition. There was always a terminal near the exhibit where users were looking for answers. The multi-touch table had some small issues, most of them software related. The software was not fully stable and crashed a few times during the experiment. The participants did not seem to find this very annoying, they understood that it was still a prototype. There were two hardware problems. The recognition of the markers was not fully stable, resulting in blinking elements on the table. But the users did not mention that they found this annoying. The other hardware related problem was the recognition of fingers. The fingers of some persons were not recognized very well. It was harder for them to interact with the objects on the table. But they did not seem to mind and kept trying to move objects until they succeeded. Besides these small issues, the table itself attracted children and adults. They liked to interact with it and the interaction seemed quite natural. So overall the table and the terminals were suitable for the quest. The table was attractive and encouraged collaboration. The terminals made it possible to present personal content to users everywhere in the museum.

The last sub question investigated if the quest was suitable to give guidance. The reported scores for guidance were quite high (average of 5.22 on a 7-point Likert scale) and the participants did not feel lost (average of 5.56 on a 7-point Liker scale). No comparison was made with a regular visit to Museon (without the collaborative quest), so it is impossible to tell if the reported guidance in the quest was an improvement. On the open question "What did you not like" seven times the answer "I found it hard/impossible to find the answer" was given. So seven of the 36 children found it hard to find the answer to at least one of their questions. This can mean that they knew at which exhibit they could find the answer, but that they could not find the right information at the exhibit. It can also mean that they could not find the related exhibit. In this case the participants were kind of lost, because they did not know where to go next. But it is unlikely that this was the case, because each question had a help button that showed the exhibit where the answer could be found.

With the answers on the sub questions the main question can be answered. The question was if the educational and fun experience of a museum visit can be enhanced by personalization. The collaborative quest showed that it is possible to create a museum experience that scores high on the fields of education and enjoyment. The initial conclusion is that only the educational experience of a museum visit can be enhanced through personalization. In the next sections a deeper analysis of the results is given. With the insights of these sections the main question is finally revisited.

6.2 Conditioning, education and enjoyment

An important question is if the conditioning worked. Only a few differences were found between the two conditions. One general explanation for this is that it might be the case that the ceiling effect caused by the high scores for enjoyment and education masks the factor personal interest. This factor, personal interest, was very important for this research. A few questions were asked to find out if there was a difference in reported personal interest between the two conditions. There were no significant differences between the two conditions for children regarding reported personal interest, but for adults a significant difference was found. Adults in the normal condition scored higher than adults in the inverse condition. This means that adults who got questions about the topics they had indicated as interesting, actually found the questions and items more interesting than the adults who did not get questions about the topics they had indicated as interesting. So for adults the conditioning worked.

The subscale for personal interest of children showed no significant difference. A possible explanation can be found in the item selection at the table, which was a very important part for the personalization of the quest. It can be questioned if the selected items really represented the personal interest of participants. This mechanism was not tested with a separate pilot test, for future research it is recommended to test this part. But the results of the adults showed that the item selection caused a difference in interest and that the selection mechanism at the table worked, so there might be other explanations for differences between children and adults regarding the reported personal interest.

A first possible explanation lies in the subscale used to measure reported personal interest, which had a Cronbach's Alpha of 0.516. It might be possible that the children did not understand all the individual questions for the subscale.

A second possible explanation can be found in the height of the scores. For both conditions the scores were above the 5.5 on a 7-points scale, making it plausible that a ceiling effect masks the factor personal interest.

A third possible explanation can be found in the theory about interest. In Section 2.4 the difference between personal interest and situational interest is described. Personal interest is a relatively stable motivational orientation that develops over time and situational interest is transitory, environmentally activated and context-specific [53]. The conditioning at the table is based on personal interest, participants should select topics they already found interesting. Because the exhibits in Museon are not about everyday topics for children, they can be relatively new to them. It might be the case that children did not already know what they found about all the topics. So there is a chance that children found out that the topics they had not selected as interesting because they were not entirely familiar to them, became interesting when they saw them in the exhibition. So at the table the item selection is based on personal interest, but during the quest situational interest can also play a role. The subscale for interest measured the reported interest of participants, where both personal interest and situational interest are of influence. For adults most topics are more common, making it easier to indicate their personal interest. Children are also into learning. They find learning natural and have a lot of curiosity [30]. So children can still be curious to topics they had not indicated as most interesting, because of their general curiosity.

Their curiosity and the environment can be a good explanation for the high scores on the perceived interest for children in the inverse condition. Together with a possible ceiling effect, this gives a explanation why no difference for reported personal interest of children was found.

For children a difference was found in education. The measure for *understanding* in the final game gave a difference. Participants with the normal condition made more good connections in the final game than participants with the inverse condition. A first possible explanation for this finding could be that the participants whose preferences were used, had more interest in the topics and acquired more knowledge than the participants in the other condition. A second possible explanation could be that the participants already knew more about the topics they indicated as most interesting. So they already had the knowledge and did not acquire it from the quest. If this would have been the case, participants would probably have had higher scores in the middle part, which tested the factual knowledge of the participants. Moreover, participants would probably have answered the questions faster. Both were not the case. A third possible explanation can be found in the learning theories. In the constructivist view of learning the knowledge of people is determined by prior experiences, beliefs and mental structures that are used to interpret objects and events. The realities of different persons are shared with each other by the process of social interactions. This corresponds with the quest. Users answer the questions with help of their existing knowledge and can update their mental structures with the information in the exhibition. At the final game they have to share their realities, because the final game is about all the individual quests together. This sharing results in a group score. The difference in understanding can be caused by only a subset of the group. A possibility is that adults had a higher contribution to the group score. But there were no significant differences for *remembering* between adults and children ($Z=-0.565$, $p=0.572$), so there are no indications that the adults had a higher contribution. It is interesting to know the individual contributions to the score, so more can be said about individual *understanding*.

Education was also tested for *remembering*, but the measures used for this showed no differences between the two conditions. The scores for the multiple choice test were low (average of 2 out of 4) and the scores of the twelve questions of the middle part were quite high (an average of 18.11 attempts to answer the questions. The minimum was 12 and a lower score is better). So the participants were

mostly focused on getting the answers on their questions and were not looking for other information in the museum. The exploratory behavior was only limited to the twelve questions.

According to Bloom's Taxonomy students functioning at the *understanding* level have also mastered the lower *remembering* level [10]. This corresponded with the results of the middle part (*remembering*) and the final game (*understanding*). The scores for *understanding* were good and the scores for *remembering* were quite high.

6.3 Constraints and improvements

There were several things that could be improved to obtain more reliable results. First of all the software for the table. The prototype that was used was not fully stable. Some crashes occurred. And although the participants understood that it was a test with a prototype, unstable software can influence the results.

To measure education, three measures were used besides observation. The measures measured different aspects of education, but not the pre-knowledge of participants. This was not done in this research because there was only limited time available for each test group and pre-tests to measure pre-knowledge can have influence on the rest of the quest. In Section 6.4 a suggestion for measuring pre-knowledge and some other suggestions for measuring education are given.

The subscales used to measure the different constructs scored not very high on Cronbach's Alpha tests. Only the subscale for enjoyment based on the Intrinsic Motivation Inventory had a Cronbach's Alpha above the 0.7, but only for adults. Some of the questions might have been too difficult for children to understand the intention of them. To make the subscales more reliable, it should be tested if the questions are comprehensible for children and test the same construct. Pilot-tests should be used for this.

Finally, subjective measures like questionnaires have some drawbacks. For example satisficing and language effects, which are mentioned in Section 6.4.2. With triangulation, this is the concept of using multiple methods to check results, one can have more confidence in the results because different methods lead to the same result [30]. Checking subjective measures with objective measures, like observation, can be useful in future research. Objective measures are measures that can be assessed with logged or observed data [30] and do not have all of the drawbacks of subjective measures.

For this research the observations were done by making notes of interesting behaviour and noteworthy cases. This resulted in incomplete data, which makes it hard to tell something about the whole population. It is more interesting to make the observations for all the groups. With complete data it is easier to tell if an observation is true for more groups, or that it was just coincidence. The two conditions can also be compared if all groups are observed, in this case observation is used as objective measure to check the findings based on subjective measures.

The following observations were interesting for this research and can be worth to take another look on for similar future research. At the table participants "stole" items from each other. For all users the attempts to steal items can be counted. The reaction of the victim can be noted. This tells something about collaboration and if participants really wanted specific items. In several scenes explanation texts were used to tell the group what to do. Text located in the center caused different behaviour than text located in front of every user. It can be interesting to observe for every user and scene what the exact behaviour was. The physical location of users (for example all at one side), turn taking (simultaneous reading or in turn) and collaboration (individual reading or reading aloud for whole group) are some of the things that can be observed. For collaboration in general it is interesting to measure when users are working alone or together at the table. When the exact time is measured, the ratio between individual and group work can be calculated. This last point is also interesting for the middle part. When are participants working alone and when are they helping each other? And if they are helping each other, how are they doing that? They can for example help group members with answering the questions or help locating the exhibit where the answer can be found. For individual members it is interesting to see how they answer the questions. They can get help from a team member, they can answer the question without help, they can let a team member answer the question or they can guess the answer. Finally the responses on the individual and group score can be observed. How many times are the scores checked and what is the reaction to it?

6.4 Theoretical and practical implications

This section looks at the implications of this research for the used theory and the methodology and concludes with practical implications.

6.4.1 Theory

Several theoretical concepts were used to make the quest collaborative, enjoyable and educative. Education was stimulated by providing feedback after correct and incorrect answers, by rewarding good answers and by punishing incorrect answers. A group score and goal were provided to stimulate cooperative learning. Enjoyment was stimulated by giving the users a clear and reachable goal, by giving them control by letting them select their own topics (for the inverse condition participants selected topics, but they were not used, so they were not really in control) and again by using punishment and rewards to extrinsically motivate them. Collaboration was stimulated by giving the participants individual tasks but with a common goal and by making use of a multi-touch table. Most concepts seemed to work. Participants were monitoring their individual and group scores and responded to changes in the scores. The punishments and rewards also worked. Participants were motivated to obtain a good score and were visibly disappointed or happy when their answer was incorrect or correct. This was both true for the middle part (responses to questions) and the final game (responses to connections). Feedback after incorrect answers helped the visitors to remember correct information. In the final game an average of three incorrect connections was made, which was quite low. Finally, the table was suitable for collaboration (see Section 5.6), especially the scenes with shared elements.

6.4.2 Methodology

Survey methods for children face several challenges. Satisficing is one of the challenges [44]. Satisficing occurs when a respondent gives superficial responses to questions, but the responses are still generally reasonable or acceptable. When children misunderstand a question or find it hard to answer, they often 'satisfice'. Toolkits designed for children can help in designing surveys. For this research the fun toolkit [43] was used to measure fun for the separate parts of the quest. Tools used were the Again - Again table and the Smileyometer. Shields et al. [55] indicate that Visual Analogue Scales, like the Smileyometer, are usable for children older than seven year. In Read and MacFarlane [44] the fun toolkit was evaluated and one of the findings was that the Smileyometer is more useful for older children. An experiment showed that almost half of the children between 7 and 9 rated everything five out five. Only a few percent of the children between 10 and 12 rated everything five out of five.

The scores in this research were also quite high and it was checked if satisficing was an explanation for this. For the begin and the middle part, the scores measured with the Smileyometer were significantly higher for children between 7 and 9 compared with children between 10 and 15 (begin part: $Z=-2.331$, $p=0.200$, middle part: $Z=-2.277$, $p=0.023$). However, the final part showed no significant difference. Where in the begin and middle part the highest score was selected more often by younger children than older children (begin part 58.3% vs. 16.7%, middle part 83.3% vs. 45.8%), no difference was found for the final part (both groups 41.7%). This shows that younger children were able to indicate how much fun they found an activity. They have the tendency to select the highest ratings, but they also select lower ratings. Where the average score for older children (10-15) for both the middle part and final part was 4.21, the scores for younger children (7-9) were 4.83 for the middle part and 3.92 for the final part. So for younger children the Smileyometer is useful, but it is good to keep in mind that scores get lower as children get older.

Language effects are another concern that is important to consider in surveys for children. Questions should be clear and understandable. When they are not, it is hard for children to give reliable answers. For the subscale for enjoyment the Intrinsic Motivation Inventory was used. In McAuley et al. [33] and Tsigilis and Theodosiou [60] support was found that the scale was reliable. The results presented in this thesis showed that the scale was only reliable for adults and not for children. When the IMI is used, the questions should be rewritten for children and tested for validity. So both the questions (understanding) and the answers (satisficing) influence the reliability of surveys for children. It is suggested to use also measures that are independent of children's ratings, like observation.

Remembering and *understanding* were measured to give an indication of education. No pre-test was taken to measure the pre-knowledge of visitors, because when the pre-test was taken before the experiment, all topics should be covered. This would take too long and could have influenced the selection mechanism at the table. But when pre-knowledge is measured, more can be said about obtained knowledge. A solution for future research is to take a test between the begin and middle part, when participants already have selected their preferences. The participants have to answer the questions they will get in the middle part, but without looking for the answers in the exhibition. After that they can resume with the actual quest. The same test can be conducted after the experiment. This results in three moments with the same test; before the middle part, during the middle part and after the middle part. The first test shows what the participants already knew, the second what they could score when they had the possibility to look for the answers and the third shows what they have *remembered*. The same concept of measuring the same construct at different moments can be done in the final game, to measure *understanding*. After the begin part the final game is directly offered to the participants, but it is not showed if the connections are correct or incorrect. After that the participants can proceed with the original quest. When they are finished, the scores of the two final games can be compared and checked for differences caused by the middle part. This way it is easier to find out what the educative contribution of the quest really is.

At the table participants had to select items to indicate their personal interest. In the questionnaire after the experiment several questions were asked to measure reported personal interest, to check if the selection mechanism at the table worked. But the measure for reported interest measures not only personal interest, but also situational interest. During the quest participants saw many new exhibits and objects, that could have triggered their situational interest. These new and interesting exhibits and objects can also contribute to the reported interest. No literature was found about the contributions of personal and situational interest to reported interest. In Chen et al. [5] an instrument was developed to measure five dimensions of situational interest and they made a distinction between high and low interest activities. This instrument could be used to measure situational interest, so that it could be checked what the contribution of situational interest to the reported interest was. New research focusing on the contribution of personal interest to reported interest or on a method of measuring reported interest could be very interesting.

6.4.3 Practice

Two variants were developed. In the normal variant users had to select topics they found interesting and these topics were used to generate a personalized route through the museum. In the inverse variant users also had to select topics they found interesting, but the topics they did not select were used to generate a route through the museum. The results show that differentiation on personal interest was not very beneficial. Both variants score high on education and enjoyment. For education the scores for *understanding* were better for the normal condition, so if only one variant can be used, the normal condition is recommended. This variant is also preferable for adults. Adults in the normal condition reported that they found the questions and exhibits more interesting than adults in the inverse condition. Because the results of the two variants do not differ very much, it can be interesting to replace the individual item selection at the table with a group item selection variant, focusing more on collaboration/cooperation, one of the wishes of Museon. In this variant the group can select items at the table and individual players get questions about the same topics. In the constructivist view of learning is stated that people share realities by the process of social interactions. With questions and knowledge about the same topics, it might have a positive effect on the sharing of realities, making the realities of individuals regarding the topics more complete. This could be positive for education.

One of the things that could be done to improve the museum-going experience according to Kotler and Kotler was improving the guidance [24]. Museum-fatigue and support in finding ones way through the museum were things that could be improved. The design of the collaborative quest helped against both problems. Users indicated their interests and with the interests a route through the museum was generated. The questions were ordered according to the structure of the exhibition. Children reported that they did not feel lost, which means that the quest gave them support finding their way. Children still had some difficulties locating exhibits or objects in the museum. This is a point that can be improved to further enhance the guidance, for examples by giving more clues where an answer can be found. Children were enthusiastic during the whole quest and all the children completed the quest. So the

problem of museum-fatigue, where visitors skip the last part of an exhibition because they are tired, was not observed. Figure 6.1 shows the average attempts for the twelve questions in the middle part. The average duration of the middle part was one hour and eleven minutes, and the duration of an average visit to Museon is about two hours. According to Davey [7] museum fatigue sets in after 30-45 minutes. So it is expected that the average attempts become higher near the end of the quest, when there is museum-fatigue. But this was not the case. So the quest improved guidance, but participants attention was limited to the questions. However, several adults mentioned that they saw interesting things they did not get questions about, and they were going to visit after the experiment. Regarding guidance the quest gives visitors a playful guide through a subset of the exhibition. With this first visit participants have an idea what the exhibition offers and can visit the exhibition more extensive after the quest. It is still interesting to observe the behaviour of visitors after the quest, so more can be said about this subject.

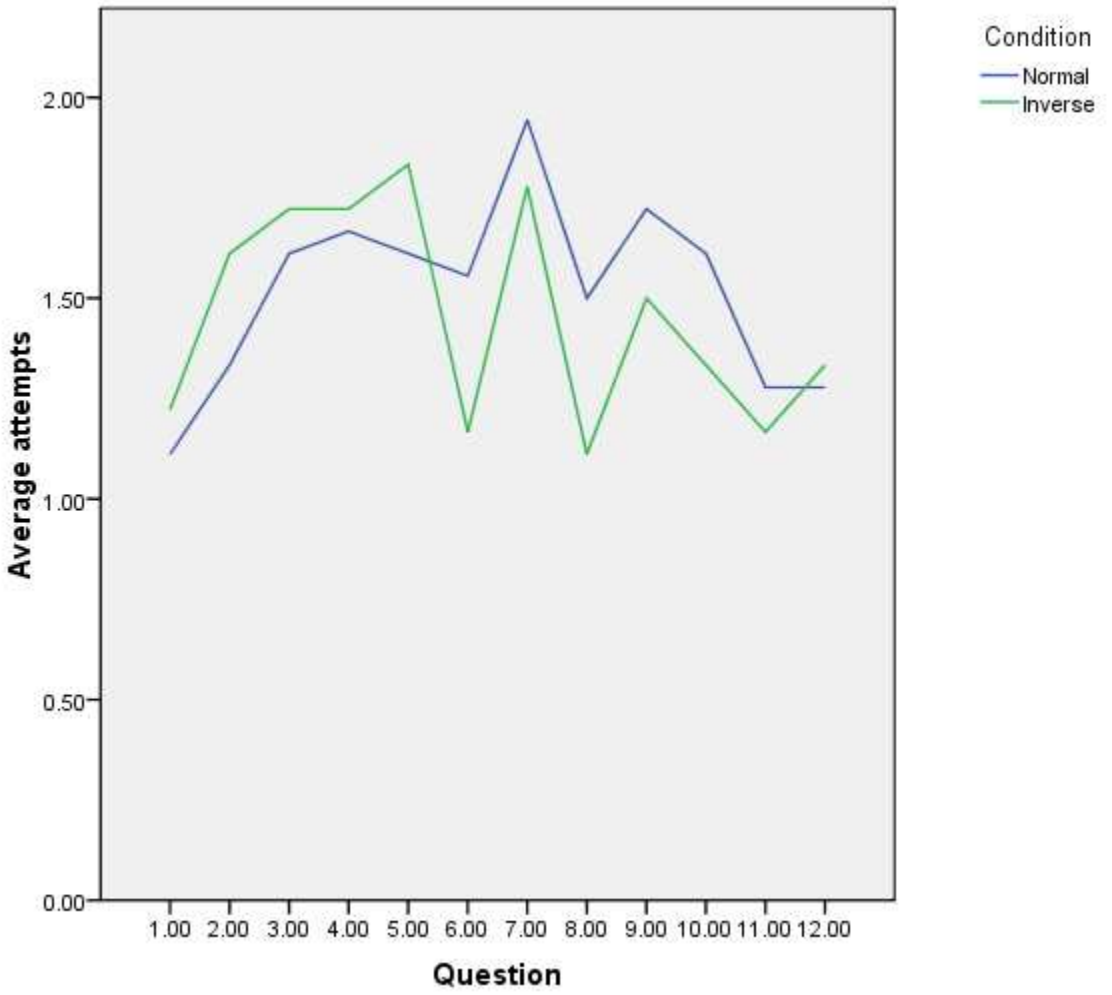


Figure 6.1: Average attempts in the middle part. The lines show no indications of museum-fatigue.

For this research multi-touch guidelines for multi-touch tables were composed. The guidelines can be found in Chapter 3. *MT1* suggested to give users a private workspace in front of them. The participants indeed worked mainly in front of them, which was in line with the theory behind the guideline. The shape of the table and the location of the tickets helped the users to take place at the edges. When the application is more focused on cooperation than collaboration or individual work, it is suggested to skip this guideline and use central shared elements. The solution used for the central voting mechanism with the sliders worked ok (*MT2, MT10*). All users could drag their sliders to indicate that they were finished,

preventing unwanted scene switches. The use of sliders is also advisable to help against accidental touches (*MT6*). The feedback on every interaction made it clear that the table could be used simultaneously, and worked as an implementation for *MT4*. For children this guideline, that tells that it should be made clear that the table can be used simultaneously, should be optional. Children just tried everything on the table and found out the functionality by themselves. Adults were more cautious and found it normal to wait for another person to finish. For them the guideline is important. The guideline for orientation (MT8) can be implemented, but users found other solutions against the orientation problem. When a text or image was not readable because of the orientation, they just walked to another part of the table so they could read it, or they asked group members to help them. Pressing a button can have a lasting effect, but accidental touches have no effect on sliders. Elements should be large enough for different finger sizes (*MT7*) and suitable for interaction with a single finger and interaction with multiple fingers (*MT9*). Some children hold two fingers against each other and tried to grab items with those fingers. This can be a problem with some multi-touch tables, which try to recognize the shape of individual fingers, preventing accidental touches with the hand or other objects. This software can conflict with the way children interact. Two implementations of the multi-touch requirements did not work well. This were *MT3*, which is about the difficulties children have with drawing straight lines, and *MT5*, which warns for the lack of a physical border around the table. Some children in the final game had difficulties with drawing straight lines between keywords and items (*MT3*). Participants could decrease the distance between items and keywords by grabbing items and bringing them near the keywords, making it easier to draw a line. But they did not make use of this functionality, so some unintended connections were made. A way to remove connections should be a better solution for this problem. With this solution users are able to correct the unintended connections. So the theory behind *MT3* is supported and it is important to take the guideline into account. The solution for the lack of a physical border around the table did not work in the group scene (*MT5*). The idea was to avoid placement of button near the edges. But the buttons for language switching were still too close to the edges. People lent on the edges, pressing the buttons accidentally. A simple solution for this is to use more space between buttons and edges or ask for confirmation after a press on buttons located near the edges.

6.5 Future work

This section gives some recommendations and suggestions for future research.

Multi-touch guidelines for multi-touch tables It will be interesting to start a new research regarding the guidelines for multi-touch tables. These guidelines can be found in Section 3.1. In the new research the guidelines of this research can be revisited and tested with a new, independent prototype. It can be interesting to test if the guidelines are applicable in different settings, for different tasks and for different target audiences. This can support new developers in the development process of multi-touch applications.

Education goal Participants were told to do their best, to get a high score, to collaborate and to have fun. Education was not mentioned to them as one of the goals. It should be interesting to find out what the influence is when learning is explicitly mentioned as the goal of the quest or when visitors visit the museum with an educative approach. Museon offers special educational activities to schools. Children visit the museum with their school and get lessons about the topics Museon offers, related to the educative goals of the school. These children visit the museum for education. Regular visitors can visit for education, leisure or other reasons. It is interesting to investigate if the different kind of visits also result in different findings regarding guidance, collaboration, enjoyment and education.

Personalization The item selection screen is a very important part of the quest. The idea is that the selected items lead to a quest along exhibits and objects which visitors find most interesting. The function of the items is important, because visitors use the items to indicate what they find interesting. For this research the exhibits were used as base for the selection mechanism at the table. The exhibits were divided over twelve categories and visitors had to use these categories to indicate what they found interesting. The criteria for the categories were that each category should represent the exhibits in it and that the meaning of the category should be clear to the user.

It can be interesting to conduct a research where this is done the other way around. Instead of using the exhibits as base, interests of children can be used as base. So the items at the table are not directly linked to topics from the museum, but to more general topics that are interesting for children. With a small research, the areas children find interesting can be listed. This can be done for example by first taking general topics that children find interesting, for example sport, school and candy, or more specific soccer, reading and ice-cream. Each topic is represented by an image and a method should be used that let the children rate the images as interesting or not. This results in topics children find interesting and topics children find less interesting. These interest areas can be used as a base and the exhibits can be divided over the interest areas. An advantage of this approach is that the items used at the table are probably more clear. But it can be difficult to divide the exhibits over the interest categories. The results can be compared with the results of this research, to find out the influence of the selection mechanisms.

6.6 Conclusion

With the interpretation of the results and the preceding discussion, the research question is revisited.

> *"Can the educational and fun experience of a museum visit be enhanced by personalization?"*

The initial answer was that the educational experience of a museum visit can be enhanced through personalization. This answer is still valid. But with the high scores of the measures, more can be said about the challenge to maintain the museum integrity as a conserving and educational institution on one hand, and make the museum more competitive and popular on the other hand. The collaborative quest showed that it is possible to create a museum-going experience which guides the visitor through the museum and is both educative and enjoyable.

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Appendix A

Questionnaire

The questionnaire used. Behind the questions that use 7-point Liker scales, the constructs they measure are indicated between brackets.

Vertel ons over de speurtocht!

We zouden je graag een paar vragen willen stellen over de speurtocht.

- Mijn naam is .....
- Ik ben ..... jaar oud.
- Hoe vaak ben je dit jaar al bij Museon geweest? Kruis een van de antwoorden aan.

Dit is de eerste keer	1 keer	2 keer	3 keer	Vaker dan 3 keer
☐	☐	☐	☐	☐

- Hoe vaak ben je dit jaar al bij andere musea geweest? Kruis een van de antwoorden aan.

Nooit	1 keer	2 keer	3 keer	Vaker dan 3 keer
☐	☐	☐	☐	☐

Hoe leuk was het?

Hieronder worden een paar vragen gesteld over onderdelen van de speurtocht. We zijn benieuwd hoe leuk je het vond. Hieronder staat eerst een voorbeeld, daarna komen de echte vragen.

Voorbeeld *Dit is een voorbeeld om te zien hoe je de antwoorden aan kan kruizen. Bij de echte vragen mag je dus op dezelfde manier een van de smileys aankruisen en een vinkje zetten bij Ja/Misschien/Nee.*

Jullie hebben een onderdeel van de speurtocht bezocht.

Hoe leuk was dit onderdeel? Kruis een van de gezichten aan.

Zou je dit onderdeel nog een keer willen doen?

Ja	Misschien	Nee
	✓	

Vragen
Jullie mochten eerst bij de tafel je naam schrijven en plaatjes uitzoeken bij de tafel.

Hoe leuk was dit onderdeel? Kruis een van de gezichten aan.

Zou je dit onderdeel nog een keer willen doen?

Ja	Misschien	Nee

Daarna gingen jullie naar boven vragen beantwoorden.

Hoe leuk was dit onderdeel? Kruis een van de gezichten aan.

Zou je dit onderdeel nog een keer willen doen?

Ja	Misschien	Nee

Op het laatst kwamen jullie weer bij de tafel voor een spel.

Hoe leuk was dit onderdeel? Kruis een van de gezichten aan.

Zou je dit onderdeel nog een keer willen doen?

Ja	Misschien	Nee

Een paar vragen

We hebben nog een paar vragen. We zullen eerst een voorbeeld geven.

Voorbeeld

Dit is een voorbeeldvraag, zodat je kan zien hoe je antwoord kan geven. Er wordt eerst een vraag gesteld. Daarna staan er 7 hokjes om antwoord te geven. Je mag een van de hokjes aankruisen. Het hokje helemaal links betekent dat je er helemaal niet mee eens bent. Het hokje helemaal rechts dat je er helemaal mee eens bent.

- *Ik vind het moeilijk om deze lijst in te vullen.*
  Helemaal niet mee eens ☐ ☐ ☐ ☐ ☐ ☑ ☐ Helemaal mee eens

Vragen

Nu volgen de echte vragen. Lees ze goed en beantwoord ze een voor een.

- Ik vond deze speurtocht saai.(Enjoyment)
  Helemaal niet mee eens ☐ ☐ ☐ ☐ ☐ ☐ ☐ Helemaal mee eens
- Ik had liever vragen over andere dingen gehad.(Personal interest)
  Helemaal niet mee eens ☐ ☐ ☐ ☐ ☐ ☐ ☐ Helemaal mee eens
- Ik vond de dingen die tijdens de speurtocht gezien heb interessant.(Personal interest)
  Helemaal niet mee eens ☐ ☐ ☐ ☐ ☐ ☐ ☐ Helemaal mee eens

- Ik vond het erg leuk om deze speurtocht te doen.(Enjoyment)
  Helemaal niet mee eens ☐ ☐ ☐ ☐ ☐ ☐ ☐ Helemaal mee eens
- Ik voelde me verdwaald in het museum.(Guidance)
  Helemaal niet mee eens ☐ ☐ ☐ ☐ ☐ ☐ ☐ Helemaal mee eens
- Deze speurtocht was leuk om te doen.(Enjoyment)
  Helemaal niet mee eens ☐ ☐ ☐ ☐ ☐ ☐ ☐ Helemaal mee eens
- Ik had liever andere dingen tijdens de speurtocht gezien.(Personal interest)
  Helemaal niet mee eens ☐ ☐ ☐ ☐ ☐ ☐ ☐ Helemaal mee eens
- Ik had liever andere dingen tijdens de speurtocht gezien.(Enjoyment)
  Helemaal niet mee eens ☐ ☐ ☐ ☐ ☐ ☐ ☐ Helemaal mee eens
- Ik zou de speurtocht als erg interessant beschrijven.(Enjoyment)
  Helemaal niet mee eens ☐ ☐ ☐ ☐ ☐ ☐ ☐ Helemaal mee eens
- Ik wist niet waar ik dingen kon vinden in het museum.(Guidance)
  Helemaal niet mee eens ☐ ☐ ☐ ☐ ☐ ☐ ☐ Helemaal mee eens
- Terwijl ik met de speurtocht bezig was, moest ik denken hoe leuk ik het vond.(Enjoyment)
  Helemaal niet mee eens ☐ ☐ ☐ ☐ ☐ ☐ ☐ Helemaal mee eens

Een kleine quiz

Tijdens de speurtocht heb je een heleboel vragen beantwoord. Over deze speurtocht hebben we nog 4 extra vragen, die je op kan halen bij de begeleider.

Boven elke vraag staat een nummer. Schrijf deze ook bij je antwoord op.

Vraag _____: .....
Vraag _____: .....
Vraag _____: .....
Vraag _____: .....

De laatste 3 vragen

Bij de laatste 3 vragen mag je zelf een antwoord opschrijven. Schrijf zoveel op als je weet. A.

A. Welke dingen van de speurtocht vond je leuk?
....
....
....
....
B. Welke dingen van de speurtocht vond je niet leuk?
....
....
....
....
C. Kan je opschrijven wat je tijdens de speurtocht allemaal gedaan hebt?
....
....
....
....
....
Bedankt voor het meedoen. We hopen dat je het leuk vond!

Appendix B

Consent form

Participants had to sign a consent form to give permission for the video recording. This appendix shows this consent form.

MUSEON

UNIVERSITEIT TWENTE.

Toestemmingsverklaring opnames (video)

Voor het onderzoek wat ik uitvoer voor mijn afstuderen aan de Universiteit Twente, is het belangrijk dat ik zoveel mogelijk gegevens verzamel tijdens de testen in Museon.

Omdat het lastig is om tijdens de test voldoende aantekeningen te maken, worden de handelingen aan de tafel gefilmd met behulp van een camera boven de tafel. De camerabeelden zullen alleen gebruikt worden voor analyse en niet verder verspreid worden.

Voor het filmen hebben wij uw schriftelijke toestemming nodig. Uiteraard kunt u op deze verklaring, mocht u daar aanleiding toe hebben, terugkomen.

Gegevens kinderen
Naam: _____ Geboortedatum: _____
Naam: _____ Geboortedatum: _____
Naam: _____ Geboortedatum: _____

Gegevens ouder/begeleider
Naam: _____ Geboortedatum: _____

Hierbij verklaar ik, dat

□ Ik toestemming geef mijn kinderen en mijzelf tijdens de onderdelen van de test bij de tafel te filmen. Het beeldmateriaal zal enkel voor analyse gebruikt worden.

Daarnaast kan het mogelijk zijn dat beeldmateriaal gebruikt wordt ten behoeve van bijvoorbeeld een publicatie of presentatie. Vanzelfsprekend zullen wij u daar apart toestemming voor vragen. Mocht u hier aan mee willen werken, dan kunt u dat hieronder aangeven.

□Ik stel het opgenomen beeldmateriaal beschikbaar voor doeleinden als publicatie of presentatie.

□Ik overweeg het beeldmateriaal beschikbaar te stellen voor doeleinden als publicatie of presentatie. Mocht dit materiaal nodig zijn, dan kan contact opgenomen worden via het volgende e-mailadres _____ @_____ . _____

Aldus opgemaakt in tweevoud en getekend,

Datum en plaats _____ Datum en plaats _____
Naam ouder/begeleider _____ Naam student UT _____

Handtekening ouder/begeleider Handtekening student UT

Appendix C

Map of Museon

Museon has two floors. The entrance is on the first floor. Figure C.1 shows a map of the first floor of Museon. The multi-touch table is located next to the main entrance. The red box in the map represents the multi-touch table. The terminals on the second floor are displayed as small boxes with a red border. A map can be found in Figure C.2. The exhibition Your World, My World covers the whole second floor. For the experiment two of the rooms (*Water, bron van het leven* and *Poolzaal)* and the central part were used. The other rooms were accessible, but the quest did not contain questions about them.

Figure C.1: First floor of Museon.

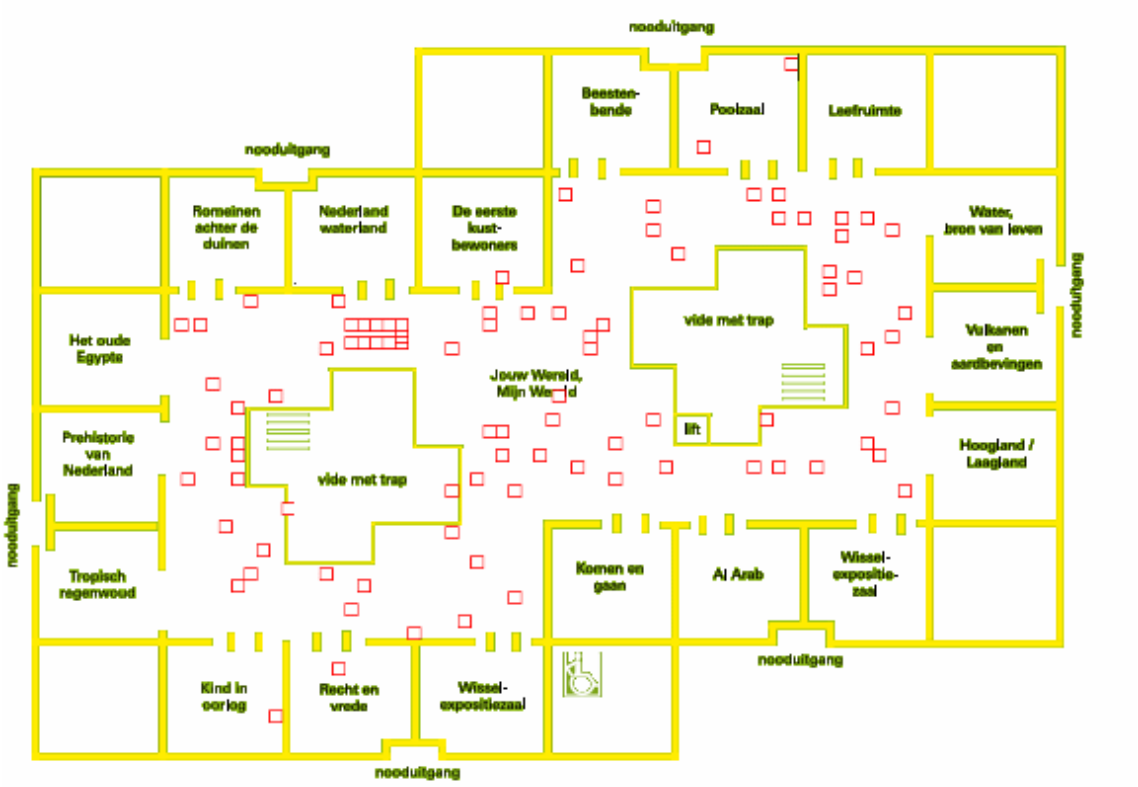


Figure C.2: Second floor of Museon.

Appendix D

Questions middle part

In the middle part five different type of questions were used. This appendix gives for each type two example questions. The questions are in Dutch.

Example questions

Multiple choice

The user must pick one answer from multiple options.

Example questions 1
Welk mineraal is dit?

- Pyriet
- Bergkristal
- Gips
- Aragoniet

Example question 2
Kijk bij de opstelling over windmolens.
Hoe moet een windmolen ten opzichte van de wind staan zodat hij het best kan draaien?

- Wind van voren
- Wind van links
- Wind van rechts
- Wind van achteren

Multiple response

The user must select one or more correct answers from multiple options.

Example question 3
Welke van onderstaande zinnen zijn waar? Meerdere antwoorden zijn goed.

- Andrewsarchus was een zoogdier.
- Andrewsarchus was een aaseter.
- Andrewsarchus was een planteneter.
- Andrewsarchus leefde in de tijd van de dinosaurussen.

Example question 4
Om onzichtbare goden en geesten grijpbaar te maken, geven mensen hen een lichaam, een masker en prachtige kleding.
Ga naar de Jipae en bekijk het goed.
Welke drie materialen zitten in dit pak?

- Riet
- Veren
- Hout
- Diamanten
- Ivoor
- Zand
- Haar

Sort object order

The user must arrange the elements in the correct order.

Example question 5
Ga naar het onderdeel over water met de blauwe vormen op de grond.
Zet de waterkringloop in de goede volgorde. Start met Regen en sneeuw vallen neer.

- Regen en sneeuw vallen neer
- Water stroomt over het land naar de rivier
- Rivierwater eindigt in zee
- De zon zorgt voor verdamping
- Wolken drijven naar het land

Example question 6
Ga naar de opstelling over de energiebronnen: kolen, olie en gas. Als je deze energiebronnen met elkaar en met windenergie vergelijkt, dan zie je dat ze niet allemaal even lang meegaan.
Zet deze energiebronnen in de goede volgorde. Begin bij de energiebron die het eerste op is.

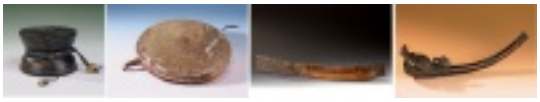
- Aardgas
- Olie
- Steenkool
- Wind

Point & click

The user must touch the correct part of an image.

Example question 7
Kijk in de tentoonstelling bij de gewassen.
Waar komt de aardappel oorspronkelijk vandaan? Toets het juiste gebied aan.

Example question 8
Kijk in de vitrines naar de verschillende instrumenten.
Welk instrument is een snaarinstrument? Druk op het juiste instrument.



Match

The elements at the right side on the screen must be dragged to the corresponding labels at the left side on the screen.

Example question 9 Ga naar het onderdeel Waterverbruik in de Waterzaal.
Zet het gemiddelde watergebruik per dag op de goede plek.

0.5 liter	Water drinken
1.5 liter	Handen wassen
10 liter	Lekkende kraan
37 liter	Toilet gebruik

Example question 10 Kijk achter de muur bij de trap.
Sla op de trommels en luister naar de verschillende tonen.
Maak de zinnen af:

Hoe LANGER de buis,	hoe LAGER de toon.
Hoe KORTER de buis,	hoe HOGER de toon.

Example question post test

In the post test four multiple choice questions to measure education are asked. The questions of the middle part are used, but they are transposed to multiple choice questions.

For example, the variant for Example question 7 in the post test was the following question.

Example post-test question
Waar komt de aardappel oorspronkelijk vandaan?

A. Zuid-Amerika

B. Afrika

C. Europa

D. Azië

Answers on the questions

This section contains the answers on the sample questions.

Question1: Pyriet

Question2: Wind van voren.

Question3: Andrewsarchus was een zoogdier, Andrewsarchus was een aaseter.

Question4: Riet, hout, veren.

Question5: Regen en sneeuw vallen neer, Water stroomt over het land naar de rivier, Rivierwater eindigt in zee, De zon zorgt voor verdamping, Wolken drijven naar het land.

Question6: Aardgas, Olie, Steenkool, Wind.

Question7: A: De aardappel komt oorspronkelijk uit Zuid-Amerika. Rond 200 na Christus zijn de indianen aardappels gaan verbouwen.Na de ontdekking van Amerika namen de Europeanen de plant mee naar huis. Eeuwenlang was de aardappel het hoofdvoedsel voor de armen.

Question8: Heel goed. Dit is een luit uit Indonesië (de derde)

Question9: Water drinken, Handen wassen, Lekkende kraan, Toilet gebruik

Question10: Hoe LANGER de buis, hoe LAGER de toon. Hoe KORTER de buis, hoe HOGER de toon.

Appendix E

Keywords final game

In the final game visitors have to connect images with keywords. This appendix gives an overview of the used images. Below each image the corresponding keywords are indicated.

										
Delfstof		✓	✓							
Dinosaurus				✓	✓	✓	✓	✓	✓	
Evolutie				✓	✓	✓	✓	✓	✓	✓
Fossiel							✓	✓	✓	✓
Geologie	✓	✓	✓				✓	✓	✓	✓
Leven				✓	✓	✓	✓	✓	✓	✓
Natuur	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Kunst										✓
Mineraal	✓	✓	✓							
Nagemaakt					✓			✓		
Opgezet			✓			✓				
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Steen	✓	✓					✓		✓	✓
Uitgestorven				✓	✓		✓	✓	✓	
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Vliegen								✓		
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Water	✓	✓								✓
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Dinosaurus										
Evolutie	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Fossiel	✓	✓	✓	✓	✓	✓	✓	✓		
Geologie	✓	✓	✓	✓	✓	✓	✓	✓	✓	
Leven	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
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Opgezet										
Plant	✓									
Steen			✓	✓	✓		✓			
Uitgestorven	✓	✓	✓	✓	✓	✓	✓	✓		
Vis				✓	✓					✓
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Water	✓	✓	✓	✓	✓				✓	✓
Zoogdier						✓	✓	✓		
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Leven	✓	✓	✓	✓	✓	✓	✓			
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			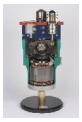							
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Echt	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
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Dinosaurus	✓	✓	✓							
Evolutie	✓	✓	✓							✓
Fossiel										
Geologie					✓	✓	✓	✓	✓	
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Natuur	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
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Mineraal					✓	✓	✓	✓	✓	
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Opgezet	✓	✓	✓							✓
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Vis	✓	✓		✓						
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Zoogdier				✓						
Energie				✓						
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Volkenkunde										
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Techniek				✓	✓					
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Vervoer						✓				
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Vis			✓		✓					
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Water			✓	✓	✓					
Zoogdier			✓							
Energie					✓					
Religie								✓		
Volkenkunde										✓
Kind			✓	✓			✓	✓		
Techniek				✓						
Model		✓	✓							
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Strijd						✓	✓	✓	✓	✓
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Metaal				✓						

							
Delfstof	9						
Dinosaurus							
Evolutie						✓	
Fossiel							
Geologie							
Leven		✓		✓		✓	
Natuur	✓				✓	✓	✓
Kunst	✓				✓		
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Opgezet						✓	
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Water		✓				✓	
Zoogdier		✓		✓	✓	✓	✓
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Kind		✓					
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Metaal							

Appendix F

Exhibit categorization

The exhibits were divided over twelve categories. Table F.1 in this appendix gives an overview of which categories and exhibits were related. The names of the exhibits are in Dutch.

Category	Exhibit
Stones	Mineralen, Bijzondere gesteenten
In the water	Het water uit, In het water
On land	Van dino tot vogel, Andrewsarchus
In the air	Loopvogels, Vogelvlucht
Sea	Zee, Mangrove
Prehistory	Evolutie, Mijlpalen in de evolutie
History	Domesticatie, Arena
Energy	Fossiele brandstoffen, Kernenergie, Alternatieve energie, Energie in de toekomst
Religion	Ei (exhibit in de vorm van een ei, over geloof), Godenbeelden
Art	Kunst, Muziek
Water	Water, Water als delfstof
Climate	Klimaat, Poolzaal

Table F.1: Exhibit division over categories