Master's thesis

NTNU
Norwegian University of Science and Technology
Faculty of Information Technology and Electrical Engineering
Department of Computer Science

Hanne Brynildsrud

Using gamification elements in an app to motivate children to learn science in an informal setting

Master's thesis in Informatics
Supervisor: Sofia Papavlasopoulou
Co-supervisor: Michail Giannakos and Kshitij Sharma
June 2022

NTNU
Kunnskap for en bedre verden

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Abstract

The science curriculum at schools has lacked relevance and connection to real-life situations for many years, which means that students have a hard time applying the knowledge they learn in school in their everyday lives and bridging the gap between science and reality. Additionally, science is perceived to be an inquiry-based subject, which calls for its teaching to be inquiry-based rather than direct instruction-based. An increasing part of formal education takes place through game-based learning and gamification, showing promising results educationally. Through creating an application with gamification elements, this thesis investigates *how the use of gamification elements in an app motivates children in learning science in an informal setting.* To address this objective, an experiment-based app called Experiverse was developed, and a mixed-method study was conducted, consisting of questionnaires, log data, and interviews to assess the app.

This thesis has contributed to a deeper understanding of how children interact with apps and gamification elements, how they are motivated to learn science through these elements, and how they view scientific experimentation. The study identifies that the relationship between autonomy, freedom, and control is complicated in terms of learning. The learning environment also play an important role when investigating the efficiency of gamification elements in an application. Research in an informal setting can thus give a better understanding of how to bridge the gap between formal and informal science learning.

Sammendrag

Læreplanen i naturfag på skolen har manglet relevans og tilknytning til hverdagslige situasjoner i mange år, noe som gjør at elevene har vanskelig for å anvende kunnskapen de lærer på skolen og knytte en sammenheng mellom naturfag og virkelighet. Naturfag er i utganspunktet også et undersøkelsesbasert fag, som betyr at undervisningen i større grad burde vært undersøkelsesbasert snarere enn instruksjonsbasert. En økende del av utdanningen skjer gjennom spillbasert læring og gamification, som viser lovende resultater for læringsutbyttet. Gjennom å lage en applikasjon med gamification-elementer, undersøker denne oppgaven *hvordan bruken av gamification-elementer i en app motiverer barn til å lære naturfag i en uformell setting.* For å undersøke dette ble det utviklet en eksperimentbasert app kalt Experiverse, som ble testet og evaluert gjennom en studie med kombinerte metoder, bestående av spørreskjemaer, bruksdata og intervjuer.

Denne oppgaven har bidratt til en dypere forståelse av hvordan barn samhandler med apper og gamification-elementer, hvordan de motiveres til å lære naturfag gjennom disse elementene, og hvilke tilnærminger og holdninger de har mot eksperimentering. Studien identifiserer at forholdet mellom autonomi, frihet og kontroll er komplisert når det gjelder læring. Læringsmiljøet spiller også en viktig rolle når man skal undersøke effektiviteten gamification-elementer har i en applikasjon. Forskning i en uformell setting kan dermed gi en bedre forståelse av hvordan man kan bygge bro mellom formell og uformell naturfagslæring.

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Hanne Brynildsrud

Trondheim, June 2, 2022

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Acronyms

ATE Attitude towards experiments. 45, 46, 47, 48, 58

ATGS Attitude towards games in science education. 45, 46, 47, 48, 58, 59

ATL Attitude towards learning. 45, 46, 47, 48

ATS Attitude towards science. 45, 46, 47, 48

AVV Avatar view visits. 48, 49

BPV Battle pass visits. 48, 49

EC Experiments completed in app. 47, 48, 49

EGL Experience with gamified learning. 40, 45, 46, 49

EU Ease of use. 41, 49

EVV Experiment view visits. 48, 49

EWU Enjoyment and wish of use. 41, 42, 46, 47, 48, 49, 55, 58, 59

GM Gamification and motivation. 41, 42, 46, 47, 48, 49, 55, 56

IC Interest and confidence. 41, 46, 49

LOA Learning outcome of app. 41, 42, 46, 47, 48, 49, 58

PLOE Perceived learning outcome of experiments. 46, 47, 48

SDT Self-Determination Theory. 8, 17, 18, 56, 58

STEM science, technology, engineering and mathematics. 12, 19

TT Total time spent in the app. 48, 49

Chapter 1

Introduction

Science-related subjects are some of the most influential subjects that children learn at an early age due to their ability to teach them to make observations, collect data, and come to conclusions logically [Beckett, 2021]. Skills like these are extremely valuable in everyday life. Additionally, research shows that children's interest in science decreases or increases between the ages of 10 and 14 depending on their learning foundation and areas of interest [Bonnette et al., 2019]. The need for ways to maintain and encourage this knowledge and experience is evident.

Innovative approaches such as including gamification elements in education have become increasingly common in everyday learning for children and young adults. Unlike their parents, today's children are digital natives, raised on the internet and other modern information technologies, such as iPads and high-tech mobile phones. Consequently, they have a different perspective than older generations who have not been exposed to modern technology as much. Nowadays, a lot of formal education takes place online through game-based learning. One of these solutions is Numetry, a math game where children between the age of 8-12 can learn mathematics through exploring a game universe of space ships and avatars, solving missions along the way [Eduplaytion, 2021]. Another is Minecraft, which initially was a 3D sandbox game, but now has come with an education edition, where children can learn about several subjects, such as science, computer science, and math, through exploration, trial and error [Studios and Studios, 2016]. In addition, there are also many opportunities for learning outside the classroom, through trips to science centers and museums, amongst other things [Kim and Dopico, 2016].

1.1 Problem description

Previous research has shown how game-based learning and gamification for educational purposes affect learning. It shows promising results in the educational manner [Huang and Soman, 2013; Butler and Ahmed, 2016; Papastergiou, 2009]. Nevertheless, minor research is conducted on how informal learning in science education can affect learning outcomes, and often focuses on gamification as a whole. The existing solutions also focus on education done in the classroom and not outside of school. Even though informal learning situations at science museums are considered an essential part of science education, most children's extracurricular activities do not fit into this category.

Furthermore, research in science education fails to account for the learning happening outside of school due to the difficulty of evaluating such a wide range of subjects and everyday learning situations [Gerber et al., 2001]. Hence, the focus of this report is to figure out how gamification elements in an app can motivate children to learn science in an informal setting. Research done by Habgood and Ainsworth [2011] showed that children playing a game with intrinsic integration improved their performance the most in an educational game. Another longitudinal study discusses the disadvantages of gamification in the classroom, which showed that giving rewards for a task one already finds interesting ends up harming the motivation to do that task [Hanus and Fox, 2015]. Another study done by Mekler et al. [2017] supports this study, stating that *points, levels, and leaderboards functioned as extrinsic incentives, adequate only for promoting performance quantity*. This emphasizes the importance of focusing on the intrinsic rather than the extrinsic motivation of children, as the application should be used because it is fun to use and because the user will feel satisfied rather than feeling compelled to use it for its learning outcomes. Hence, the report focuses on how using an app with gamification elements can motivate children in science outside of school.

One way to prevent the decreasing interest in science is to make the learning more inquiry-based and practical. It has been shown that an inquiry-based activity, such as experimentation, can help children become more interested in science as a result of being physically engaged in it [Lumpe and Oliver, 1991]. In addition, it appears that informal science experiences in elementary school can encourage interest in science, technology, engineering and mathematics (STEM) subjects, which can lead to further participation or a STEM career [Bonnette et al., 2019]. Another benefit of informal learning is that it makes learning fun, builds confidence, and a feeling of accomplishment for the children using it [Denson et al., 2015].

1.2 Research Question and Goal

Is it possible to create an app that engages children to become more motivated in science outside of school? This thesis aims to analyze how to motivate children in science by adding gamification elements in the context of informal science education, letting children explore through a mobile app with experiments. With this in mind, the thesis has the following research question;

> *How can the use of an app with gamification elements motivate children to learn science in an informal setting?*

1.3 Research Method

This thesis utilized a mixed-methods design to answer this research question, which combined different approaches into a triangulated approach. The study included quantitative and qualitative data by conducting and collecting interviews, questionnaires, and log data to understand what engages children's attitudes and motivations towards science through a gamified app.

1.4 Thesis Structure

The thesis consists of 9 chapters. Chapter 2 presents background theory and existing solutions. Chapter 3 describes the architecture and the design process of the developed application, Chapter 4 explains how the study was conducted and analyzed. Chapter 5 presents the findings and results from the study, which are later discussed in Chapter 6. Finally, Chapter 7 summarizes and concludes the thesis.

Chapter 2

Background and Existing Solutions

A prestudy was done regarding articles and papers concerning science learning, gamification, informal learning, and motivation. However, most papers regarding science learning apps were dated; consequently, many of the apps used outdated technology, which does not correspond with today's possibilities. Hence, there were found studies regarding how informal learning affects students and research on encouraging learning environments and teaching methods for children. There were also carried out informal, unstructured interviews with three elementary school teachers to gain current insights into what motivates children these days and what games they are typically interested in.

2.1 Definitions

2.1.1 Informal Science Education

As of today, science education takes place both in schools and outside of them, such as in museums or science centers. There is also strong evidence that most of the learning happens outside of school, according to a study done by Fallik et al. [2013]. Fallik also suggests a need to bridge the gap between learning in school and learning in an informal setting. For informal learning to be effective in science education, Kim and Dopico [2016] also argue that students' lifeworld contexts must be taken into consideration. The fact that research shows that the interest in science decreases through elementary school, and the need for including more informal learning for pupils in their everyday life substantiates the need to create platforms that motivate, and at the same time provides a knowledge building experience for the user [Bonnette et al., 2019].

The focus of this thesis is learning in an informal setting. Informal learning is opposed to non-formal learning, which refers to education that happens outside of school but is intentionally pursued. An example of this can be meeting in scout groups or sports programs. Informal learning, on the other hand, happens outside the educational system and is pursued without intention. The learning is not necessarily planned or follows any curriculum [Doe, 2018]. This study aims to create an app that can act as a motivator in that the user wants to use the app in an informal setting because it is fun and engaging rather than because they feel they need to. By allowing the user to choose the time and place when they want to use the app, the potential for an increased interest in science occurs based on the user's intrinsic motivation. The main focus is on the required skills regardless of how they are obtained, formally or informally [Khaddage et al., 2016]. However, Khaddage et al. [2016] also state some limitations to informal learning in a mobile app. It can be challenging to capture informal learning when it occurs, and there are no common key performance attributes to measure learners' progress.

2.1.2 Gamification

This thesis aims to illustrate how gamification elements can motivate in science; hence there is important to define what gamification can be. *Gamification* involves incorporating elements of gaming into nongame contexts. Such elements can be badges, leaderboards, or rewards, amongst others [Groh, 2012]. The concept of gamification motivates and engages users, and it is applicable to many fields. Gamification is on the rise, particularly in the field of education, due to its success as a motivator in a school system where motivation and engagement are declining [Lee and Hammer, 2011]. The fact that games are popular amongst children and the idea that including similar elements of a game in an educational setting contributes to why gamification can work as a motivator in learning science. Gamification also enables experimentation and repeated mistakes, which is a significant advantage as it encourages users to try again. The stakes are low because it is only possible to learn and progress in some games by experimenting and failing; this is contrary to exams and tests in school where it is possible to fail; hence the stakes are high [Huang and Soman, 2013].

2.2 Background

2.2.1 Inquiry Based Science Learning

Science education in school has lacked relevance and connection to real-life situations for a long time, which means students find it challenging to apply the knowledge they learn in school in everyday life and bridge the gap [Fallik et al., 2013]. Often science education is also too formal to generate interest amongst students. Clegg et al. [2006] investigated how to promote learning in informal environments through real-world practices and experiments and found that it was necessary to design activities that both engage and promote learning . They did this by involving children in an after-school club where the goal was to learn the scientific purposes behind cooking. The combination of cooking and investigating the scientific reactions of cooking was a good way of connecting learning to everyday life. As Havasy [2001] correspondingly states; *"When science is practical, it is more dynamic and memorable for students"*. Here, the importance of including students in the learning process through exploration and questioning is emphasized . Students are not as engaged in today's science education as they should be because the traditional way of learning is outdated and does not engage the student's motivation and interest. Even though several studies support the inclusion of more inquiry-based learning in science education, there have been minor changes in the way it is taught [Ural, 2016; Alake-Tuenter et al., 2012; Harlen, 2013].

Clegg's study also found that parents contributed to their children's learning process by assisting the hands-on experiments [Clegg et al., 2006]. Similarly, Gleason and Schauble [1999] conducted a study examining parents' involvement in their children's scientific education . Parental involvement was especially helpful in collecting evidence through experiments, but not in helping the child interpret the results since they found it difficult to understand the child's reasoning process.

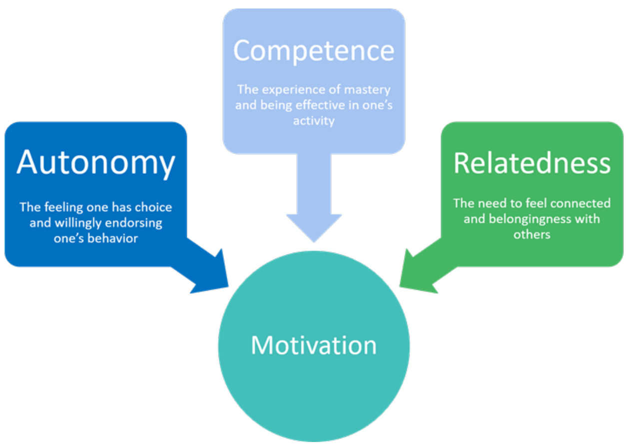
Experimenting is an inquiry-based activity that has shown great potential as a way of encouraging and engaging children in getting more interested in science. As science is perceived to be an inquiry-based subject, there is consequently a need for it to be taught in an inquiry-based manner. Lumpe and Oliver [1991] highlight that unstructured inquiry experiments engage students at high cognitive levels . This is also confirmed by Dhanapal and Shan [2014] who add to this through their findings; *"Hands-on experiments promote students' learning and build on their intrinsic motivation"*. This idea, where exploration and questioning lay the foundation for motivation and learning outcomes, corresponds well with children's exploratory stage in early adolescence.

2.2.2 Motivation

There are several theories regarding motivation in use today, and motivation itself consists of several factors which affect our behavior and thus our learning. The absence of motivation, interest, positive attitudes, and self-efficacy will lead only to limited and curtailed engagement. Without engagement, learning will be only partial at best, Fortus [2014] states. A study done by Pintrich [2003] proposed a framework for motivational science design principles where self-efficacy, adaptiveness, goals, and intrinsic motivation were some of the key principles .

Self-Determination Theory (SDT) is a theory that suggests that people are motivated to change and grow by internal factors. SDT is largely based on the fact that we become internally motivated if we experience that we have sufficient autonomy in what we are to do. There are at least three basic physiological needs in SDT. This is the need for *autonomy*, *competence* and *relatedness* as pictured in Figure 2.1 [Deci and Ryan, 2000]. If one sees this theory in the context of an app that aims to trigger the user's intrinsic motivation, three factors are important when creating an app; First, the app should encourage autonomy in that the user feels they have a choice in using the app. Second, the user should feel mastery in using the app, and third, they should feel relatedness with others.

Figure 2.1: Self-Determination Theory



Is it possible to match game elements with psychological needs? Roy and Zaman [2017] conducted a study where they introduced nine gamification heuristics based on SDT. The nine heuristics are shown in Table 2.1 along with the challenge they aim to solve. To support autonomy, one should avoid obligatory uses of the system and provide enough meaningful choices. Confidence is built through challenging but manageable goals and positive feedback. Lastly, the system should facilitate social interaction to fulfill the need for relatedness.

Table 2.1: SDT gamification heuristics

Challenge	**Heuristic**
Support learner's autonomy	#1 Avoid obligatory uses #2 Provide a moderate amount of meaningful options
Support learner's competence	#3 Set challenging but manageable goals #4 Provide positive, competence-related feedback
Support learner's relatedness	#5 Facilitate social interaction
Interplay between needs	#6 When supporting a specific psychological need, be careful about preventing other needs
Integration of gamification into the activity	#7 Align gamification with the goal of the activity in question
Contextual characteristics	#8 Create a need-supporting context
Individual characteristics	#9 Make the system flexible

SDT is thus closely related to the inquiry-based nature of science due to the aspects of autonomy, competence, and relatedness. A study done by Lavigne et al. [2007] found that there was a significant difference in intrinsic motivation and identified regulation among students with a positive attitude towards science versus a low attitude towards science. *Intrinsic motivation* is defined as motivation to do something for oneself rather than for some outer reward or product. Lavigne's findings are consistent with another study where they explored whether science labs could foster students' autonomy and intrinsic motivation [Thomas and Müller, 2014]. Results of this study support the notion that enhancing autonomy support can counteract the decline in intrinsic motivation that occurs during early adolescence.

2.2.3 Gamification in Education

As students experience adverse emotions in science education and have trouble associating concepts with real-life situations, digital technologies, such as gamification, can play an essential role in influencing the learning process [Bonnette et al., 2019]. Gamification in education is on the rise, but the elements of gamification often focus on the extrinsic motivation of the user, with points, competition, and leaderboards being the most popular ones. Habgood and Ainsworth [2011] investigated the learning outcomes of intrinsic integration versus extrinsic integration in gamified learning and found that children learned more from the intrinsic version of the game. Despite this, the results fluctuate as to whether gamification encourages the user's intrinsic or extrinsic motivation.

Nevertheless, several studies show an increase in motivational outcomes when implementing gamification as a part of education. The purpose of gamification in learning is to make learning more attractive for students by allowing trying and failing. Hursen and Bas [2019] did a study where they investigated children's interest in science before and after using a gamified application for learning science in school. The results showed that the gamification application positively affected motivation in learning science, and it was concluded that it was the game elements that stimulated interest in science. Similarly, Ding et al. [2017] suggest that badges, feedback, progress bars, and avatars are among the features in their study that promoted student engagement. Brewer et al. [2013] also found that points and prizes served to motivate the users in their study in a lab environment. They also suggested to consider increasing challenges and adding narratives when implementing gamification elements in a learning environment.

2.3 Review of Existing Solutions

Several apps on the market regarding learning through video games and digital platforms. This section presents a review of similar apps within the STEM field that has been used as inspiration for the app's concept. Listed below are apps that allow learners to learn the curriculum through gamification and game-based learning, with an emphasis on those that are used in the Norwegian school system and were mentioned in the unstructured, informal interviews with teachers Section 2.4.

2.3.1 Nysgjerrigper.no

Nysgjerrigper is a site created by the Research Council of Norway (Norges forskningsråd) Forskningsrådet [2021]. The Research Council is a Norwegian government agency that funds research and innovation projects. Nysgjerrigper is the Research Council's offer to pupils and teachers in primary school. Their goal is to get more people to know what research is about and make more people want to work with research. The site lists experiments within different categories, ranging from autonomy to the solar system and science. These experiments are the ones that have been used in the app, which is elaborated more upon in Subsection 3.4.1.

2.3.2 Numetry

Numetry is a Norwegian-developed story- and character-driven mathematics game [Eduplaytion, 2021]. The children are sent on a journey to discover the solar system Matema, where math skills take them further in the galaxy. Numetry aims to make math learning fun and exciting. The development team consists of experienced teachers and skilled game developers. Numetry is also anchored in the curriculum for 4-7th grade. Håvard Tjora, one of the teachers behind Numetry, states three main factors that make game-based learning engaging for children. First, it presents the curriculum differently. Secondly, it offers problem-solving through the tasks in the game. There are no straightforward calculations but rather missions to be accomplished. Thirdly, game-based learning allows the user to try and fail, which is the prerequisite for thinking creatively.

2.3.3 DragonBox

DragonBox is a complete course in mathematics for primary school. The curriculum has been developed according to new curricula with support from the Norwegian Directorate of Education. The goal of DragonBox is to bring math to life. The four steps of the curriculum are exploration, conversation, exercise, and summary. A study was done on whether this solution was effective on 1407 first and second-graders of primary school in the Lillestrøm region. The results show that the pupils in the group that used DragonBox performed significantly better on the mathematics test, in opposition to the ones who did not [Vennerød-Diesen et al., 2021]. In accordance with research done by Tisza et al. [2020], children become interested in a topic when they are exposed to it through something they find intriguing, through a playful approach.

2.3.4 Go-Lab

Go-Lab is a website with a collection of online labs where children can do experiments on the website [De Jong et al., 2014]. The website is an initiative to encourage students to become engaged in science topics through online science labs. Additionally, the research states that there need to be global efforts taken to produce skilled and enthusiastic scientists at an early age. Go-Lab provides both virtual labs and teacher training to facilitate students' use of the labs in their education.

2.3.5 COMnPLAY Science

In COMnPLAYer, COMnPLAY Science aims to encourage children to discover and learn about science through fun and interactive games. It includes several stories that explore the idea of science capital. The concept of science capital encompasses all the resources, ideas, and experiences that a child may possess related to science. The stories in the app are linked to quizzes that encourage users to think about their science capital, where the responses will be used for research purposes [Giannakos and Grammenos, 2018].

2.3.6 Minecraft Education Edition

Minecraft Education Edition is an educational version of Minecraft which is specifically designed for being used in the classroom [Studios and Studios, 2016]. As Minecraft is a sandbox game, it gives the users lots of freedom and allows them to use their creativity when playing. Minecraft Education Edition offers different worlds within different subjects so that the player can learn about anything from designing for accessibility to learning about cyber safety through investigating, analyzing, and solving problems.

2.4 Insights from Teachers

Unstructured, informal interviews were conducted with three elementary school teachers before and during the prototyping and ideation phases. The purpose of the discussions was to gather ideas and understand what interests children in a learning environment from a teacher's perspective. The discussions revolved around what games children play nowadays to what they think is most interesting in school.

The first teacher, who taught elementary school pupils from years 1-4, said that experiments were among the most intriguing and exciting things children did. A solution would be to ask the pupils to write what they did as part of the experiment, what they discovered, and perhaps include a photo of it as part of the app to validate the experiments presented in the mock-ups. The teacher also observed that children love it if they could change their avatar's clothes and names and buy new things, amongst other things.

The second teacher educated pupils in elementary school from years 5-7. She added that it would be nice to have a function in the app where teachers could access what pupils have been doing in the app. She also mentioned that children are bad at receiving verbal messages, so another feature could be to be able to send notifications and messages in the app. Regarding the app's community function, she said that if the app were used in a school setting, it could create unwanted pressure on the children, while if it was used in an informal setting outside of school, this might not be such a problem. The teacher also added that to validate the experiments, one could ask the children to write a hypothesis of what they think would happen. Then, after experimenting, they could answer what happened.

The third teacher also educated children in elementary school from years 5-7. She stated that one of the most popular games used for educational purposes these days is Minecraft and that the children would rather play Minecraft than do anything else. However, she emphasized that for such an app to work, it had to be fun to use and have game elements, such as in Minecraft, where one learns through playing the game.

2.5 Positioning the Current Study

It is important to note that the background and existing solutions presented in this chapter represent only a selection of the related work and are not intended to serve as an exhaustive preliminary study. Instead, this chapter aims to identify areas where research is lacking and gather valuable insights on how the app's development phase would proceed. Several apps explore gamified learning as an in-app experience, such as the Go-Lab website or Numetry, while apps targeting experiments in a real-life situation were not found. The uniqueness of this app rests in its ability to offer experiments on the go, making it flexible; characterization with an avatar, making it adaptive; and the fact that it should not be used in an educational setting, making the user autonomous. The goal of the Experiverse app is to target children's curiosity, motivating them to acquire knowledge through experiments while also making it fun. There is no time limit and allowance to try and fail. Apps like this pose novelty in that it offers the user a combination of technology and hands-on experience with experimenting, targeting the autonomy of the player [Roy and Zaman, 2017].

Chapter 3

Design and development

This chapter gives an overview of the process of designing and developing the mobile application and the choices made along the way. It is structured by first presenting the requirements of the app, the design journey, and then its architecture and implementation.

3.1 Requirements

To be able to deliver a prototype that could be tested on children, some requirements had to be put down. As the idea behind the app was to implement gamification elements to trigger the children's motivation, as stated in Section 1.1, it was essential to focus on storytelling and prototype an app that encouraged curiosity and motivation. Therefore, the app's background story and visual elements were as important as the actual experiments, the app's main feature. The requirements were developed through findings from the literature study and informal, unstructured interviews with teachers as described in Section 2.4. Specifically, the heuristics presented in Table 2.1 were taken into consideration when designing the system, as well as the badges, feedback, progress bars, and avatars that Ding et al. [2017] promoted in their study. The requirements consisted of functional and non-functional requirements, as listed in the tables below. Since the app was not to be used in a controlled setting, the app had to have a low error rate and a high level of usability, maintaining the users' interest over a more extended period.

3.1.1 Functional Requirements

Functional requirements describe a specific functionality of a system and what this functionality should do in order to be completed [Wikipedia, 2022a]. When developing functional requirements, the goal was to be able to deliver a prototype of the product with the most important features, therefore there are some must-have functionalities, as well as some non-planned functional requirements, which were functionalities that were planned to implement, but due to the time frame and technical issues, they were not implemented. A complete list of the user stories can be found in Appendix B.1.

Must-have *requirements:*

- User should have different experiments on each planet [Roy and Zaman, 2017]
- The user should be able to write a hypothesis to the experiment
- A user should be able to choose an avatar [Roy and Zaman, 2017]
- A user should be able to see what their score is at all times
- A user should be able to see what their progress is, both in the experiments and in the solar system [Ding et al., 2017]
- A user should be able to see an overview of the solar system to see what they will receive, like rewards on the other planets
- A user should receive rewards when completing all experiments on a planet [Ding et al., 2017]

Non-planned *requirements:*

- A user should be able to change the avatar's clothes [Roy and Zaman, 2017]
- A user should have an onboarding to the app when logging in for the first time
- A user should be able to receive badges for completing different tasks in the app [Ding et al., 2017]
- A user should be able to interact and do experiments with friends [Roy and Zaman, 2017]

3.1.2 Non-Functional Requirements

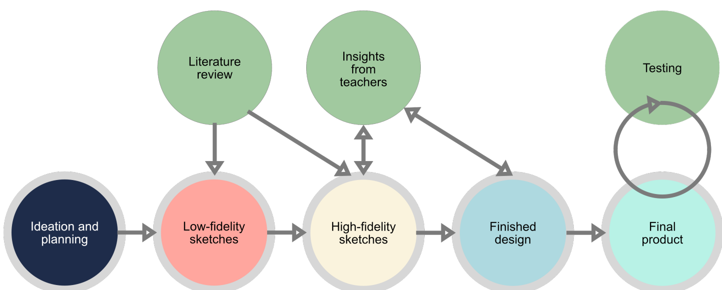
A non-functional requirement is a requirement that describes how a system should work rather than what the specific functionalities should do [Wikipedia, 2022b]. Considering that the application was to be used in an uncontrolled environment, a low error rate was necessary. The app also had to have specific security measures to comply with privacy rules for children. A list of the non-functional requirements can be found below:

- The application should have security measures such as login authentication to ensure privacy for children
- The application should have a user-friendly interface
- The application should load its content seamlessly
- The application should be responsive and work cross-platform (iOS, Android, iPad)

3.2 Iterative Design Process

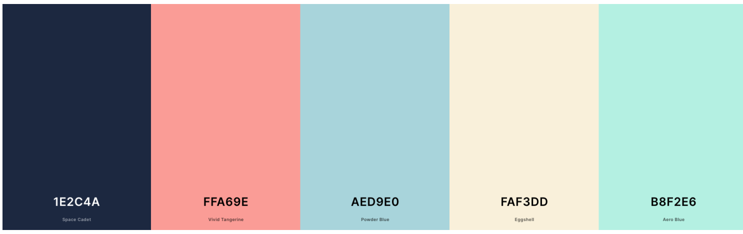
The app's design process consisted of three phases; low fidelity sketching and ideation, high fidelity sketching, and detailed designing. The three phases of designing included iterations of ideation and research, designing and re-doing the design according to feedback from testing, and the informal, unstructured interviews with the teachers in Section 2.4, which was an ongoing dialogue through the designing phase. The design process is pictured in Figure 3.1.

Figure 3.1: Design process



To gain inspiration for designing the app, [Dribbble, 2010] was the primary source, drawing inspiration from other children's apps. A color generator was used to make sure the colors were compatible, as seen in Figure 3.2. The choice of colors was based on earthy, playful, and comfortable colors suitable for the target group.

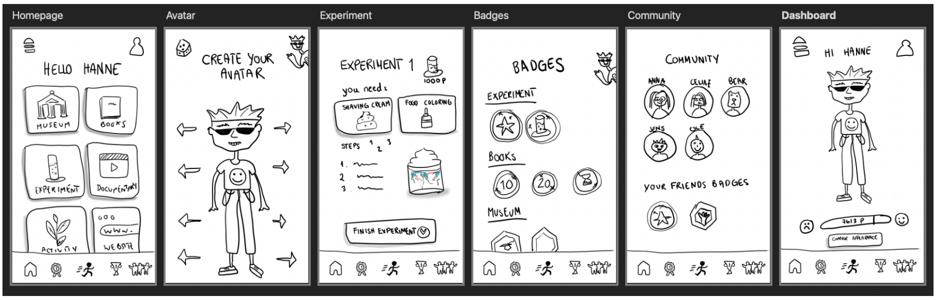
Figure 3.2: Colors



3.2.1 First Iteration

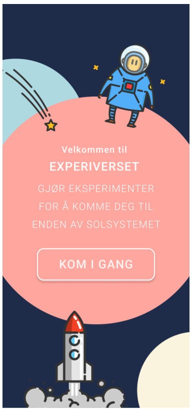
The first sketches were made using a drawing pad and Adobe Photoshop, making them low-fidelity sketches. Initially, the sketches and ideas were quite many, as the intention was to include as many learning elements in an informal setting as possible. The idea of this first sketch was that the player had an avatar they had to please through the week by doing experiments, visiting museums, reading books, and visiting internet pages, as seen on the first sketch in Figure 3.3. These sketches were made in an ideation phase, before the non-structured informal interviews with the teachers as described in Section 2.4, and before the requirements in Subsection 3.1.1 were put down. Even though these initial sketches differ quite a lot from the final prototype, the avatar view has been kept, but it has been changed to be the home view, and the experiment view also remains, with a different setup. Nonetheless, through talking to teachers and supervisors, it became apparent that the idea was too extensive for a master thesis. Therefore, due to the time constraints in the thesis, the next iteration of the design included narrowing the functionality down to focus only on informal learning through experiments.

Figure 3.3: First sketches



3.2.2 Second Iteration

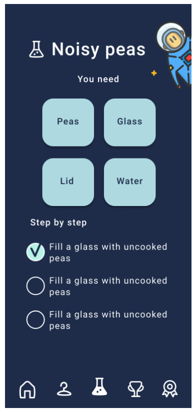
The second iteration involved more high-fidelity sketches of the application. This iteration focused on how the app should display the experiments. After being presented with the initial sketches, the teachers gave valuable feedback on the design (see Section 2.4), mentioning that both dinosaurs, space, and the solar system were themes that children would find intriguing. Therefore these were the two relevant themes for the application. The choice ended up with the theme being space and planets of the solar system, as the solar system is a part of the curriculum in elementary school. The first teacher interviewed said that children found experiments intriguing in education; therefore, experiments laid the foundation for the app (see Section 2.4. Through the use of the app, the goal was that children could learn about science through experiments and about space through its user interface. A *Get started* view, Figure 3.4a and a *Dashboard*, Figure 3.4b, were designed where the player had an overview of their progress in the app. All activities, such as museum visits, videos, etc., were reduced to only managing experiments for each planet, as seen in Figure 3.4c below; thus, this view now only included experiments for each planet. The detailed experiment has gone through several iterations in these sketches after advice from the teachers in Section 2.4 that a hypothesis would be a good idea to include in order to validate the experiments, as seen in Figure 3.4d. There is also an illustration of the ingredients in the experiments and an explanation of the step-by-step guide. Because of the focus on gamification in this thesis, an *Avatar* view and a *Badges* view were also added. Users could customize their avatars and see which badges they had received while completing experiments in the application. See Figure 3.4e and Figure 3.4f.



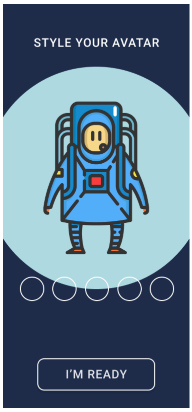
(a) Get Started

(b) Dashboard

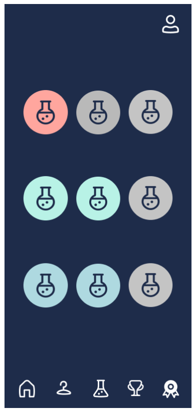
(c) Experiments



(d) Experiment



(e) Avatar

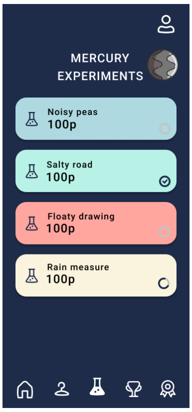


(f) Badges

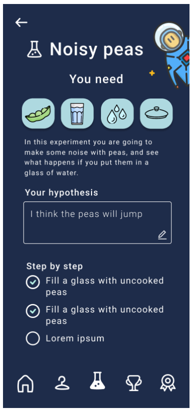
Figure 3.4: Second iteration

3.2.3 Third Iteration

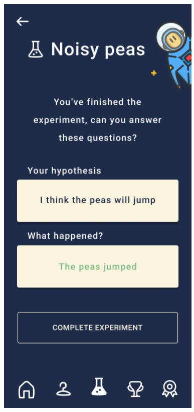
The third and final iteration of the design process included narrowing the app down to include only the most crucial functionalities for the app to be tested and working with how the experiments should be displayed. This involved removing the possibility of adding friends and customizing the avatar. Additionally, the experiment view was changed as the friend function was removed, and it was not necessary to filter the experiments based on how many users were involved.



(a) Experiments

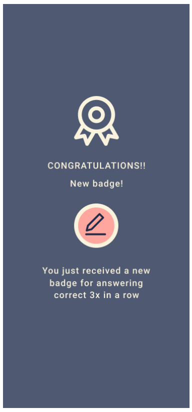


(b) Experiment

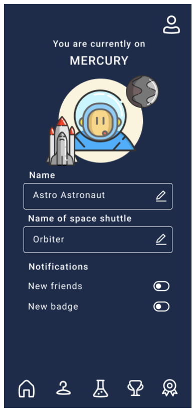


(c) Hypothesis

(d) Badges



(e) Overlay



(f) User profile

Figure 3.5: Third iteration

3.3 Experiverse Application

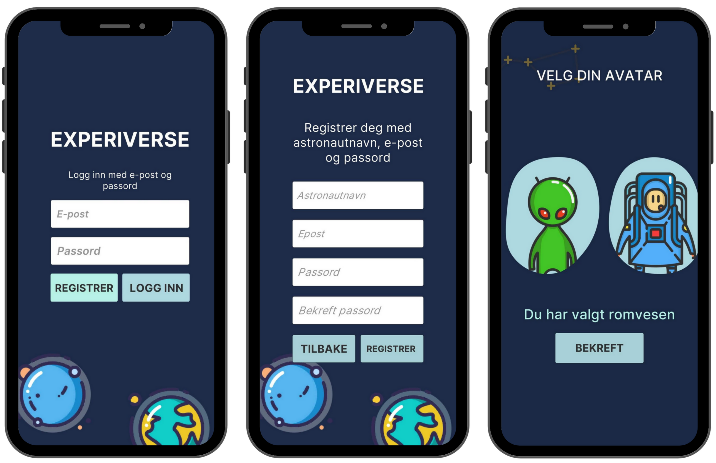
Screenshots of the final prototype, a description of each view of the app, and the choices made are included in this section. It also covers the architecture of the application.

3.3.1 Final Prototype

Due to the tight deadline, the final prototype differed slightly from the final iteration of the design process. Unity had some limitations in the state handling, so some of the elements had to be discarded. The final prototype and iteration of the design was a mix of development and changing the design simultaneously, culminating in the final prototype of the app. Currently, the app has four main views in the navigation bar, in addition to the *Login* and *Register* view and the *Battle Pass*. These views are further elaborated on below.

Login

Initially, the login and authentication included the Firebase built-in email verification. However, after testing the app on children, it became apparent that the school email they used when registering blocked emails being sent outside of the school's list of approved senders. As a result, email verification was removed from the app, while the user still had to use their email address to register and log in. To enhance the interactivity and personalization of the app, the user can choose an avatar when logging in for the first time. The final log in frames can be seen in Figure 3.6.



(a) Login (b) Register (c) Register

Figure 3.6: Login

Home

The *Home* view of the application provides the user with an overview of their current progress in the app. It displays which planet they are currently on, their avatar, their score, and how many points they have to gather before taking them to the next planet. The *Home* view is not interactive other than the possibility to click the space button in the upper right corner. The space button leads the user to the *Battle Pass* listing of all the planets in the solar system and what prizes the user will receive when completing all experiments on one planet. This view is interactive, letting users slide back and forth through the solar system and their belonging rewards.

(a) Dashboard (b) Space

Figure 3.7: Home

Experiment

The *Experiment* view has several layers, the *Experiment* view, the *Detailed Experiment* view, and the *Hypothesis* view, as seen in Figure 3.8. First, the user gets an overview of the experiment on their current planet, with their belonging scores. Then the user can click the experiment they want to perform, which takes them to the *Detailed Experiment* view as seen in Figure 3.8b. On top of the view, one can find the title of the experiment and an ingredient chip list. There is a description for each of the experiments, giving the user some valuable background information before they get started. The user should then gather all the things needed for the experiment before continuing to the next step, which is the execution of the experiment. Next, the user follows the step-by-step guide before completing the experiment and getting directed to the *Hypothesis* view. The user writes their hypothesis here, what they think is the reason why the experiment went the way it did. When writing a hypothesis with a sufficient length, the user can save it and get an explanation in the explanation field, as pictured in Figure 3.8c. This leads the user to either a *Finished All Experiments* view or a *Finished Experiment* view, based on their progress, seen in Figure 3.8d and Figure 3.8e.

(a) Overview (b) Experiment (c) Hypothesis (d) Completed experiment (e) Level up

Figure 3.8: Experiment

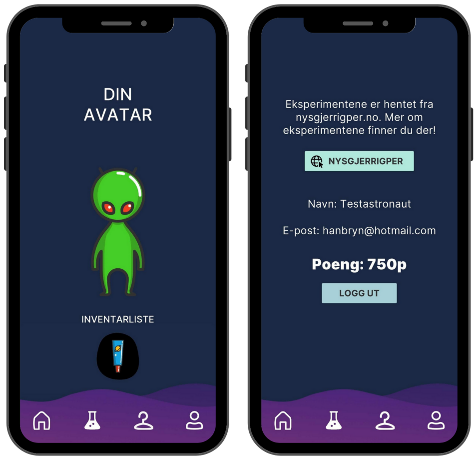
Avatar

The *Avatar* view was initially meant as a view where the user could customize their avatar with clothes and colors. However, it turned out that this would be difficult to implement in time due to the time constraints and constraints in the technology used. The solution was, therefore, to give the avatar an inventory list with the items the user received when completing all experiments on a planet, as seen in Figure 3.9a. This inventory list will update when the user progresses, but the user does not have the ability to use the items.

Profile

The *Profile* view contains a link to the page from which the experiments have been retrieved. By clicking this link, the user gets redirected to Nysgjerrigper.no, where there is a more thorough explanation of the experiments with images. The

Profile also contains the user's name and email address, as well as their total score and a logout button, seen in Figure 3.9b.



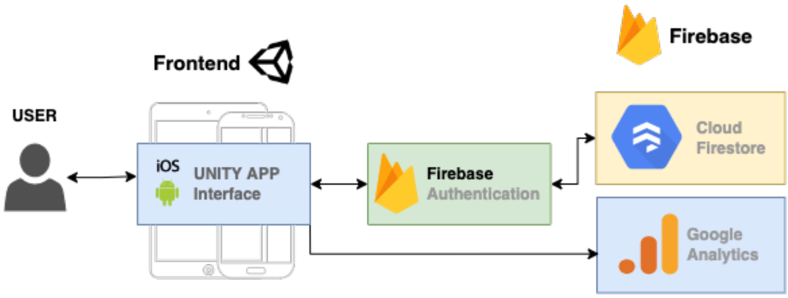
(a) Avatar (b) Profile

Figure 3.9: Home

3.4 Application Architecture

The app is a frontend application created in Unity with C#. Unity offers a cross-platform tool with minor alterations needed for building an application for both Android and iOS, which was necessary not to exclude any possible participants [Sinicki, 2020]. It was also chosen because of its ease of use in making a visually appealing and interactive UI. Firebase was used as the application requires sign-in and authentication to keep the children's data secure. In addition, it provides easy and secure SDKs for storage, authentication, and analytics, amongst other things [Google, 2011]. The application uses Firebase's Firestore Database to store user data, Authentication for handling login and authentication, and Google Analytics to analyze log files and user data. Initially, email authentication was used to verify the users, but this presented problems regarding restricted email access for the children that were to test the app. As seen in Figure 3.10, the application architecture itself is relatively simple but also scalable, as Firebase offers scalable solutions for storage and analytics.

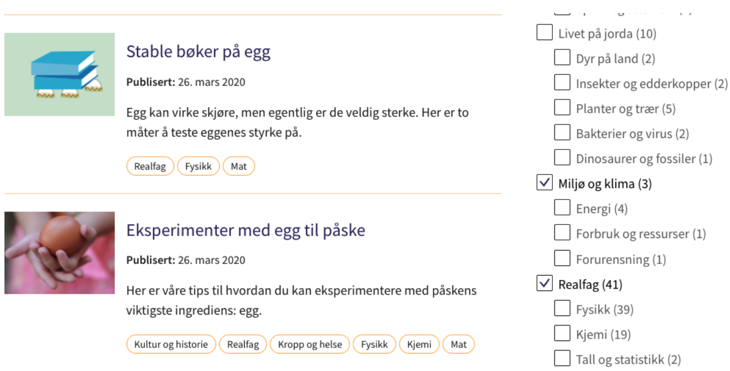
Figure 3.10: Application architecture



3.4.1 Retrieval of Experiments

The experiments in the app were copied from the Research Council of Norway's site nysgjerrigper.no. As described in Subsection 2.3.1, the site offers experiments that aim to trigger inquiry-based learning and make more children interested in science. They are primarily designed for elementary school pupils and involve creative experiments that encourage learning and reflection on various topics, including biology, environment, science, and culture. The Research Council of Norway has given written consent to use their experiments as a part of the application. The experiments were copied and rewritten to JSON and saved in the app's database, connected to a specific planet.

Figure 3.11: Nysgjerrigper Experiments



Chapter 4

Method

This chapter outlines a plan for how the study was conducted and methodological choices made. It also describes how the data was collected and analyzed.

4.1 Research Design

How can the use of an app with gamification elements motivate children to learn science in an informal setting? The research questions point to motivation in an *informal setting*. Thus, it was necessary to collect the data in an informal setting, meaning that the participants should use the application outside of school. To answer the research question, the study was a within-subjects study, combining quantitative and qualitative data to assess how children perceived and used the mobile app with gamification elements. Since the data collection was to be conducted in an uncontrolled setting, triangulation was necessary to ensure the objectivity and validity of the data. As Oates [2006] states, if the data shows consistency across research methods, it can lead to higher levels of confidence in the results, which was important given the small sample size, as outlined in Section 4.2 . The app's target group is children between 9 and 13 years of age; hence, the children recruited for testing were within this age range, although most were in the upper range of the scale. To measure the kids' perception of science and motivation by the gamification elements in the app, both a pre- and post-test was conducted as part of the quantitative research. Further, the log data from app usage was analyzed to build on the results that were mapped in the questionnaires and determine the children's level of motivation and attitude toward the app. Lastly, seven children were interviewed about their perception of science and gamification in the app after using it to gather qualitative data and verify the results.

4.2 Participants

A total of 25 participants, aged 9 to 13, took part in the study. The study recruited participants by combining convenience sampling and random sampling. The first step was to contact teachers in the circle of friends, explain what the study entailed, and ask if there was a possibility to test the app in one of their classes. Unfortunately, this initiative gave mixed results, as there were several guidelines and rules to follow when publishing an app for children to test, delaying the process of gathering participants. The convenience sampling eventually resulted in the recruitment of two classes in an elementary school in Viken County. Originally, twenty-five children obtained their parents' approval to attend the study from the two classes, but only eighteen attended the study. To recruit more participants, the Research Council's offer to primary and lower secondary school pupils, Nysgjerrigper, elaborated in Subsection 2.3.1, was contacted to increase participation through social media. As a result, eight parents of 9 children made contact through Nysgjerrigper, where 7 of them attended the study. In an effort to engage the participants, cinema gift cards were given as compensation upon completion of the study. As explained in Subsection 6.4.3, only 25 of the 31 participants who answered the pre-test were able to test out the app during user testing as a result of technical issues and parental restrictions on the children's phones. The 25 participants in the study consisted of 15 boys (60%) and 10 girls (40%) and included pupils spread across the different classes in elementary school (M = 5.4, SD = 1, min = 4; max = 7), and the ages of the target group (M = 10.96, SD = 1.02, min = 9; max = 13).

4.3 Ethical Considerations and Briefing

According to the European Commission's report on Ethics for Researchers, children should be given special consideration when they are involved in research and should only participate when it is an absolute necessity in the research [Commission et al., 2010]. The Norwegian Center for Research Data (NSD) has assessed that the processing of personal data in this project follows the privacy regulations when it comes to children. Upon receiving the approval from NSD, an information letter and consent form were mailed to the parents of children participating in the Research Council initiative and by paper to the families of children participating in the convenience sampling initiative. The information letter contained a brief explanation of the study and their children's responsibility during the first step of the study, available in Appendix A.1. As part of the consent scheme, parents were informed that their child would not be able to participate unless they completed the scheme and delivered it. Additionally, both the parents and their children were made aware that they could withdraw their consent at any time and that the study's participation was voluntary.

4.3.1 SharePoint

As a precaution and to ensure privacy, the data collected from the app, questionnaires, and interviews were stored on a secure server in Microsoft SharePoint, the cloud storage for Microsoft 365 [Microsoft, 2001]. NTNU has an agreement with Microsoft, which ensures that its data storage in the cloud is safe and accessible.

4.4 Procedure

As mentioned in Section 4.2, the participants were recruited both by convenience sampling and random sampling. The methods used to recruit the participants affected the approach taken to them. Since their parents asked them to participate and would engage their children at home, the random sampling participants tended to be more self-driven and engaged in testing the app. On the other hand, convenience sampling participants tended to be less focused on user testing. In order to bring this to the attention of both elementary school classes, an app demonstration was conducted (see Subsection 4.4.2). Research phases included a pre-test, a user-test, a post-test, and interviews, covered in more detail below.

4.4.1 Pre-Test

The participants were asked to answer a pre-test measuring attitudes regarding science and game-based learning, available in Appendix A.3. Pre-tests were digitally answered through a link prior to user-testing on their devices and could not be changed after delivery. The test included questions regarding the participants' age, gender, class, and Likert scale questions regarding motivation in science, experiments, and learning through games. The children were told that it was important that they used the same email address when registering in the app and when answering the questionnaires to make sure their user paths were trackable. The pre-test was used to collect quantitative data, described in more detail in Subsection 4.5.1.

4.4.2 Demonstration of App

In an effort to ensure that as many participants as possible from the convenience sampling group used the app during the test period, two of the experiments from the app were conducted in each of the classes of the school where the participants were recruited. The goal was to increase engagement around the app and the study and explain the app's functionality. In addition, by visiting the school, there was also possible to ensure that the participants answered the pre- and post-test. Figure 4.1 below shows pictures from conducting one of the experiments in class, making "obleck" of cornstarch and water.

Figure 4.1: Experimenting in class

4.4.3 User-Testing

Initially, the idea was that the children could download the app on the iPad they had received from school when the demonstration was done at school. However, it turned out that these iPads had a barrier to what could be downloaded, which meant that they could not get access to the app at school (see Subsection 6.4.3). As a result, the parents received a guide either through the teacher or by mail on how their child could download the beta version on their Android or Apple device. The user period was then extended to two weeks, as some children could not download the app before the second week. Upon user testing, the children were also informed that they could use the app wherever they saw fit and as much as possible for the period.

4.4.4 Post-Test

After the two weeks of user testing at home, the participants were asked to fill out a post-test measuring their motivation after using the application. The questionnaire included questions regarding learning, perceived usefulness, ease of use, enjoyment, and satisfaction with the app. Furthermore, upon completing the post-test, the children were asked whether they wanted to participate in a short interview to collect qualitative data. Finally, the users received their cinema gift card of 150 NOK as a reward for contributing to the research.

4.4.5 Interviews

The last step of the study included interviewing some of the participants to gain qualitative data for triangulation. The consent from the legal guardian had already been obtained, and the child was also informed that the participation was voluntary. Children were interviewed either in one of two ways; either in person at their school since this was convenient when they answered their post-test physically, or via video conference with the child at home. Two of the children interviewed attended 5th grade, one attended 6th grade, and four attended the 7th grade, two of them boys, and five of them girls. Interviews were conducted three to seven days after the user testing. Again, the children were informed that it was voluntary to participate in the interview and asked if they were comfortable with the interviews being recorded for transcription purposes. All interviews were done in Norwegian, as this was the native language of the children.

4.5 Data Collection

The goal of the data collection was to collect data on how the gamification elements in the app would motivate the children to do science experiments. Since the participants were between 9 and 13 of age, where the youngest children's thinking processes are based more on mental representations, there had to be adjustments in how the data was collected, to a more visual method of answering a questionnaire, with understandable text and images [Giannakos, 2022]. In addition, it was necessary to keep the questionnaire short, meaning that the pre-test consisted of six questions and the post-test of eleven, due to children's often short attention span. The data collected include log files, questionnaire data, and interviews.

4.5.1 Pre-Test

The pre-test aimed to measure the children's motivation toward science and their experience with games in education. The purpose pre-test was to gather data that could be used to measure correlation; therefore, the questionnaire was a Likert scale questionnaire of six questions in addition to the questions regarding personal information. The questions in the questionnaire were derived from the questions in the post-test questionnaire in Subsection 4.5.3, as the aim was to see if there was any correlation before and after using the app. The Likert scale has the advantage of giving data about the participants' opinions and attitudes, which are relatively easy to measure as they are ordinal. The Likert scale used in both the pre-test and post-test was a 7-point scale in the range from 1 to 7, where 1 represented answers such as "Boring" or "Low Motivation", 7 represented "Fun" and "High Motivation" and 4 was "Neutral". The complete questionnaire can be found in Appendix A.3. The Experience with gamified learning (EGL) was originally a multiple-choice question, but was changed to categorical values ranging from 0-3 for statistical purposes.

Table 4.1: Pre-test measures

Description	**Acronym**	**Value**
Experience with gamified learning	EGL	0-3 (categorical)
Attitude towards science	ATS	1-7
Attitude towards games in science education	ATGS	1-7
Attitude towards learning	ATL	1-7
Attitude towards experiments	ATE	1-7
Perceived learning outcome of experiments	PLOE	1-7

4.5.2 User Data Tracked in Experiverse

To be able to understand how the participants used the app, Google Analytics was used as integration in Firebase to track events, button clicks, and engagement time. Cocea and Weibelzahl [2011] claims that log files are a potentially valuable source to use in educational settings when recording a large number of users, as in this research design. As this study aimed to investigate how gamification elements could work as a motivator, the statistics connected to the gamification elements, such as the avatar, points, and experiments, were crucial to see if it was corresponding with the post-test. The table below presents different events and data tracked in the app to measure the user's motivation. These are measures that will contribute towards analyzing the children's motivation.

Table 4.2: Log data

Description	Acronym	Values
Total time spent in the app	TT	>0 sec
Experiments completed in app	EC	0-24
Battle pass visits	BPV	>0
Avatar view visits	AVV	>0
Experiment view visits	EVV	>0

4.5.3 Post-Test

As the use of the app and subsequently the user logs varied greatly, the data collected from the post-test was the primary source of quantitative data from the participants. Participants were asked a few similar questions in both the pre- and post-test to measure the relationship between the variables. The questions were adapted and inspired by previous studies regarding perceived ease of use [Davis and Davis, 1989], intrinsic motivation [Venkatesh et al., 2002] and fun [Tisza, 2021]. The questions in the post-test were similar to the pre-test Likert scale questions.

Table 4.3: Post-test categories

Category	Acronym	Description
Gamification and motivation	GM	Experience of storyline and motivation of points
Interest and confidence	IC	Increased interest in science and confidence in experiments
Ease of use	EU	Understanding and ease of use
Learning outcome of app	LOA	Usefulness and perception of learning performance
Enjoyment and wish of use	EWU	Experience of fun through the app

The first category of Gamification and motivation (GM) contains questions regarding the enjoyability of using the app, inspired by Venkatesh et al. [2002] questions and measures of enjoyment and intrinsic motivation. The three following categories, Interest and confidence (IC), Ease of use (EU), and Learning outcome of app (LOA)included questions adapted and modified from Davis and Davis [1989], and his measures of perceived usefulness and ease of use. The last category, Enjoyment and wish of use (EWU), combine questions and measures from Venkatesh et al. [2002] and Tisza [2021] to measure intrinsic motivation and the experience of fun. The questions from the literature were modified to fit the study and participants of the study.

4.5.4 Interviews

As a result of the participants' age, there was necessary to pay extra attention to how the interviews were to be conducted. An interview guide was prepared in advance for the semi-structured interviews. This can be found in Appendix A.2. It was essential to create contact with the interviewee for them to want to open up to the interviewer. It became apparent that several of the children did not want to participate in an interview due to shyness, not wanting to hurt the interviewer's feelings, or not wanting to join the interview on their own. As a result, there were opened up for group interviews as well, in an effort to collect more data.

4.6 Data Analysis

This section presents how the data collected was analyzed. The aim was to identify patterns in the data and evaluate this according to the research question.

4.6.1 Quantitative Data

After the data was extracted from the questionnaires and the usage logs, IBM's Statistical Package for the Social Sciences (SPSS) tool for analyzing data was used to manage the data, perform analyzes, and present results. Due to the ordinal nature of the data from the questionnaires, Spearman correlation analysis was used to analyze the numerical data [Statistics, 2018]. The Likert scale is ordinal in that, although it is obvious that "5 motivation" is higher than "2 motivation", it is not clear how motivation is interpreted since it varies from person to person. There were also conducted a test for normality of the participants' ages, with a Shapiro–Wilk test. A significance level lower than 0.05 indicates that the data cannot be regarded as following a normal distribution.

Post-Test Categories

The post-test questions were split into five different categories, according to the different sources in Subsection 4.5.3. The related questions were put together to get a more realistic overview of the participants' opinions. Cronbach's alpha was used in SPSS to measure the reliability of the categories. GM, LOA and EWU scored above the Cronbach's alpha of 0.65, which is a good indicator of an acceptable level of reliability. As a result, these are the three post-test categories used to measure correlation. Since the data were not normally distributed, the average was used to calculate the score of the categories. In Table 4.3 one can see the categories under which the 11 questions in the post-test fall with their belonging acronym and description. A complete overview of the questions can be found in Appendix A.4.

Correlation

Spearman correlation tests were done between the pre-test questions, the post-test categories, and the log data. Oates [2006] points out that any correlation between 0.3 and 0.7, both positive and negative, is considered to show a reasonable correlation, and the closer this coefficient is to 1, the stronger the correlation.

Paired Sample T-Test

In order to answer the research question, it was necessary to measure interest in science before and after using the app. Therefore, there was also carried out a paired sample t-test in SPSS. The goal was to see whether there was any significant difference in scores before and after [Oates, 2006].

4.6.2 Qualitative Data

The transcription tool in Word was utilized to analyze the qualitative data gathered from the interviews. Since the interviews had been recorded, the first round of transcription could be done using Word dictation. After the recordings had been read into Word, cleanup was done by splitting the interviews into questions and answers. Lastly, the five interviews were grouped into themes that repeatedly occurred during the interviews, which will be elaborated on in the results chapter.

There was used an inductive category development for categorizing the interviews [Mayring, 2000]. An inductive approach aims to develop themes through studying the data rather than having chosen themes or theories brought into connection with the data. The categories to which the qualitative data were dedicated emerged from several iterations of re-reading the interviews and combining similar statements to develop different themes.

Chapter 5

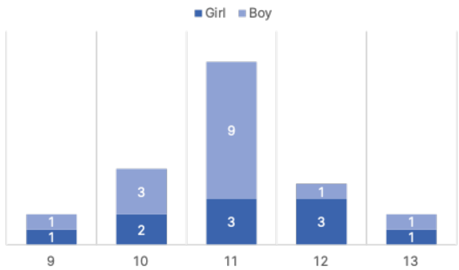
Results

This chapter will present the results coming from the quantitative and qualitative data collection described in Chapter 4. This includes descriptive profiles of the data collected, results from the Spearman correlation tests, the paired sample t-test, and the interviews. For presenting the correlations and t-test results, the acronyms of the quantitative data from Subsection 4.5.1, Subsection 4.5.3 and Subsection 4.5.2, will be used.

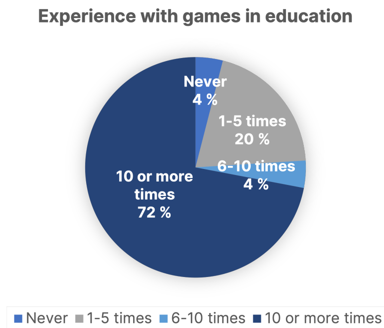
5.1 Descriptives

This section presents the characteristics of the quantitative data collected. Included are the mean and standard deviation for collected data from the pre-test, the post-test categories, and the aggregated results of the user testing. As the study is a within-subject study, the sample size is the same throughout the study (N=25) and, therefore, not included in the tables. Below, Figure 5.1a presents the distribution of the participants based on age and gender. Since there was a small sample size, a Shapiro-Wilk test was done to check for normality. This test showed evidence for non-normality ($W = .905$, $p = .023$).

Figure 5.1: Demographics and Descriptives



(a) Demographics



(b) Experience with games

5.1.1 Questionnaires

The table below (Table 5.1) presents the statistics of the six questions from the pre-test questionnaire. Figure 5.1b presents the distribution of experience with games in education amongst the 25 participants of the study. This was split into the categorical data attribute Experience with gamified learning (EGL) as described in Subsection 4.5.1, with values in range 0-3. The Figure gives an impression that the majority (72%) of the participants were familiar with games in education prior to participating in this study. This is also illustrated in the pre-test descriptive Table 5.1, where EGL has a high mean value, indicating that even though some of the participants had never used games for learning purposes, the majority of the sample size was familiar using it. A complete overview of the descriptives for each of the questionnaire questions can be found in Appendix C.1.

Pre-Test Descriptives

As seen in Table 5.1, both Attitude towards science (ATS) and Attitude towards games in science education (ATGS) contains values that extend across the entire scale. This indicates that the differences between the children's interest in games and science fluctuate. However, there is a higher mean of the ATGS, which might indicate that the children's attitude towards games in education is higher than in science itself. The standard deviation of ATGS is also higher than the other attributes, which adds to the indication that the attitudes toward using games in science education differ amongst the participants. Both Attitude towards learning (ATL) and Attitude towards experiments (ATE) have a higher minimum score than the previous attributes, which suggests that there is a higher level of agreement amongst the children towards the enjoyment of learning and doing experiments.

Table 5.1: Pre-test descriptives

	Min	**Max**	**Mean**	**Std. Dev**
Experience with gamified learning	0	3	2.44	.961
Attitude towards science	1	7	4.80	1.384
Attitude towards games in science education	1	7	5.80	1.658
Attitude towards learning	3	7	5.48	1.262
Attitude towards experiments	3	7	5.80	1.225
Perceived learning outcome of experiments	3	7	5.12	1.269

Post-Test Descriptives

The tendency of the categories from the post-test questionnaire also fluctuates in some categories. Gamification and motivation (GM) is the variable with the highest lowest observation in the data set. The standard deviation is also relatively low compared to the other categories, indicating conformity in the children's perception of gamification as a motivator in the app. Interest and confidence (IC), Learning outcome of app (LOA) and Enjoyment and wish of use (EWU) on the other hand have observations across the Likert scale, with a higher standard deviation, which indicates that the participant's benefit of use differs from user to user. As mentioned in Section 4.6.1 the fluctuating results in the IC category can be explained by the lower level of reliability.

Table 5.2: Post-test descriptives

	Min	**Max**	**Mean**	**Std. Dev**
Gamification and motivation	4.00	7.00	5.44	.905
Interest and confidence	2.00	7.00	5.46	1.513
Ease of use	3.67	6.67	5.45	.870
Learning outcome	1.00	7.00	4.16	1.650
Enjoyment and wish of use	2.00	7.00	5.30	1.428

5.1.2 Log Data

The log data contains more fluctuating data as the data is measured in clicks on the different views of the app and time spent in the app in seconds, in contrast to the Likert scales in the questionnaire. For example, one can see in Table 5.3 that the average use of the app was approximately 20 min and 55 seconds (M=1254.9). Thus, as the standard deviation here is considerable and the range of the observation is vast, it is indicated that the actual use of the app varies a lot amongst the participants, according to the statistics. This is also the case with Experiments completed in app (EC), where some have completed 0 experiments, while others have completed 19, and the average is just above 3 (M=3.20, SD=3.862).

Table 5.3: Log data descriptives

	Min	**Max**	**Mean**	**Std. Dev**
Total time used	281	4800	1254.92	1174.223
Experiments completed	0	19	3.20	3.862
Battle pass views	0	7	3.20	3.862
Avatar view visits	0	12	3.72	3.803
Experiment view visits	0	44	13.04	9.952

5.2 Correlations

The tables below give an overview of the correlations between questions in the questionnaires and the application log data. A Spearman Rank Correlation analysis was conducted to compare different variables in the pre- and post-test with the log data. The results show at which points the correlations were deemed significant.

5.2.1 Pre-Test and Post-Test

The correlations between the variables in the pre-test and the post-test is pictured in the table below. The variables compared in the table below are Attitude towards science (ATS), Attitude towards games in science education (ATGS), Attitude towards learning (ATL), Attitude towards experiments (ATE), Perceived learning outcome of experiments (PLOE), and the three categories from the post-test which scored above 0.65 on the Cronbach alpha (Gamification and motivation (GM), Learning outcome of app (LOA) and Enjoyment and wish of use (EWU)). The strongest significant correlations were found between ATL and ATS ($r = .664$, $n = 25$, $p = <.001$) and PLOE and ATE ($r = .634$, $n = 25$, $p = <.001$).

Other significant correlations between the pre-test and the post-test were EWU and ATGS (r = .529, n = 25, p = .007). This correlation indicates that there is a connection between the users attitude towards games in science education and their enjoyment of using the app.

Table 5.4: Correlations between pre-test and post-test

		ATS	ATGS	ATL	ATE	PLOE	GM	LOA	EWU
ATS	Spearman Corr. Sig. (2-tailed)	1							
ATGS	Spearman Corr. Sig. (2-tailed)	.115 .584	1						
ATL	Spearman Corr. Sig. (2-tailed)	**.664**** <.001	-.037 .859	1					
ATE	Spearman Corr. Sig. (2-tailed)	**.456*** .022	.045 .832	.366 .072	1				
PLOE	Spearman Corr. Sig. (2-tailed)	.361 .076	-.031 .882	.232 .265	**.634**** <.001	1			
GM	Spearman Corr. Sig. (2-tailed)	.374 .067	.288 .163	.272 .188	.239 .251	.243 .242	1		
LOA	Spearman Corr. Sig. (2-tailed)	.384 .058	.198 .342	.338 .099	.132 .531	.342 .094	.339 .097	1	
EWU	Spearman Corr. Sig. (2-tailed)	**.436*** .030	**.529**** .007	.236 .256	.092 .660	.158 .451	**.577**** .003	**.517**** .008	1

*.Correlation is significant at the 0.05 level (2-tailed)
**.Correlation is significant at the 0.01 level (2-tailed)

5.2.2 Post-Test and Log Data

The correlations between the categories in the post-test and the aggregated data from the Experiverse app is pictured in the table below. The variables compared in the table are Gamification and motivation (GM), Learning outcome of app (LOA), Enjoyment and wish of use (EWU), Total time spent in the app (TT), Experiments completed in app (EC), Battle pass visits (BPV) Avatar view visits (AVV) and Experiment view visits (EVV). The strongest significant correlations relevant for the thesis were found between EWU and GM (r = .577, n = 25, p = .003), EWU and LOA (r = .517, n = 25, p = .008). There is also a positive correlation between the EVV and LOA (r = .493, n = 25, p = .012), which indicate that there may be a connection in the frequency of visits of the experiments view and the perceived learning outcome of the experiments.

Table 5.5: Correlations of post-test and log data

		GM	LOA	EWU	TT	EC	BPV	AVV	EVV
GM	Spearman Corr.	1							
	Sig. (2-tailed)								
LOA	Spearman Corr.	.339	1						
	Sig. (2-tailed)	.097							
EWU	Spearman Corr.	**.577****	**.517****	1					
	Sig. (2-tailed)	.003	.008						
TT	Spearman Corr.	-.012	-.198	-.234	1				
	Sig. (2-tailed)	.954	.342	.259					
EC	Spearman Corr.	.150	.084	.026	.318	1			
	Sig. (2-tailed)	.474	.688	.903	.122				
BPV	Spearman Corr.	-.095	.168	.041	**.525****	.261	1		
	Sig. (2-tailed)	.650	.423	.846	.007	.208			
AVV	Spearman Corr.	-.302	.177	-.233	.273	.074	**.615****	1	
	Sig. (2-tailed)	.142	398	.263	.187	.727	.001		
EVV	Spearman Corr.	.180	**.493***	.277	**.492***	.261	**.641****	**.442***	1
	Sig. (2-tailed)	.388	.012	.181	.012	.207	<.001	.027	

*.Correlation is significant at the 0.05 level (2-tailed)
**.Correlation is significant at the 0.01 level (2-tailed)

5.2.3 Independent Variables

Other variables that were compared with the post-test categories and aggregated data were the independent variables age and Experience with gamified learning (EGL). In Table 5.6 one can see that there is a significant negative correlation between age and GM (r = -.570, n = 25, p = .003), indicating that the users attitude towards gamification features increases while age decreases. There is also a negative correlation between EGL and TT (r = -.526, n = 25, p = .007), demonstrating that there might be a connection between how experienced the user is with learning through games, and how much they have used the app.

Table 5.6: Age and experience correlations

		GM	IC	EU	LOA	EWU	TT	EC	BPV	AVV	EVV
Age	Spearman corr.	**-.570****	—.084	.126	-.151	-.001	.060	-.139	.221	.084	.170
	Sig. (2-tailed)	.003	.691	.547	.472	.998	.776	.507	.289	.691	.417
Experience	Spearman corr.	-.199	.169	.002	-.018	-.080	**-.526****	.025	-.360	-.190	**-.422***
	Sig. (2-tailed)	.341	.418	.992	.932	.705	.007	.906	.077	.363	.036

*.Correlation is significant at the 0.05 level (2-tailed)
**.Correlation is significant at the 0.01 level (2-tailed)

5.3 Paired Sample T-Test

A paired sample t-test was conducted to compare scores for children's attitudes towards science and the learning outcome of experiments before and after using the app. The two-tailed test will test if the average of the two scores is higher or lower in the second variable. These variables were the only ones tested due to these being consistent variables that got tested prior to and after using the app. Results showed that the participants attitude towards science (M = 4.80, SD = 1.384) was higher after using the app (M = 5.08, SD = 1.412). Nevertheless, the results showed that there was no significant difference in the scores of how children perceived science before and after using the app. Furthermore, the participants perceived learning outcome from experiments (M = 5.12, SD = 4.16) was lower after using the app (M = 4.16, SD = 1.546). The results indicate that this difference is significant, t(24) = 2.753, p = .011. This suggests that the app may not affect the learning outcome of experiments.

Table 5.7: Paired sample t-test

	t	df	Sig. (2-tailed)	Mean	Std. Deviation
Attitude towards science	-.814	24	.424	-.280	1.720
Learning outcome	2.753	24	**.011***	.960	1.744

*.Significant difference when "Sig. (2-tailed)" is less than 0.05

5.4 Interviews

This section will present the findings from the five interviews conducted through the data collection in Subsection 4.5.4. The results presented are extracted from the interviews after categorizing the statements into four different themes. The themes include motivation of use, gamification in-app, informal learning, and design implications. The extracted snippets from the interviews will be translated and presented in English, while the original interview was held in Norwegian.

5.4.1 Combination of Technology and Real-Life Experiments

One of the themes that emerged from the interviews was the app versus real-life experimenting aspect. Several of the participants expressed the combination of technology and hands-on experimenting as positive and motivational, thereby a theme evolved from the statements in the interviews, as seen below. The fact that the app encourages the user to do something physical rather than passively looking at a screen was mentioned as a positive feature. When asked what the best part of the app was, one of the interviewees said;

> *"...It must be that it wasn't just looking down at a screen. It was something you could do, too, so it was good..."*

Another participant also highlighted the same when asked why the participant would want to use the app:

> *"...I guess it was that I was at home with other people who tested the app, and we thought we could try it anyway because we had nothing to do but look at the phone..."*

A third participant reflected upon the element of combining an app with hands-on experimenting when asked if they prefer for everything to be in-app rather than in real life:

> *"...This is an experimental game, so it's better to do it in real life than to do it on a screen. So I think it's good because you can use your iPad or screen for something other than just sitting and playing on it. In addition, you learn from it..."*

Despite the positive attitude towards the mix of in-app and real-life experiences, most participants also stated that the compensation, i.e., the cinema ticket, was a motivator for using the app. When asked why they wanted to use the app, one of the participants stated:

> *"...It was a bit because I wanted to test it out because it looked quite fun, and it's also a bonus because then you don't get bored and you get gift cards as well..."*

One of the others also added to this by stating:

> *...It was exciting, and it was a bit that we got gift cards as well...*

5.4.2 Perception of Gamification in the App

When asking the participants what features they liked the best within the app, the avatar and experiment views were the most mentioned. When asked about which views and gamification features motivated the participant the most, one of them also drew attention to the battle pass view as one of their favorites:

> *"...I liked the avatar page, and I liked the page where one could browse*

through the planets. Where it says how much money or points you must have received to get to the next planet. I thought that page was cool..."

The participants were also asked what they thought about the journey through the solar system in the app, where one of them stated:

"...I also think it was pretty cool and creative because then it becomes more fun to do it so that something actually happens when you're done with the experiments. So that it's not just a text, and then nothing happens. Yes, I thought it was cool..."

When being asked the same question, one of the other participants added an idea of expanding the universe of the app:

"...It's a great way to get people to do experiments, and I think it was exciting. But it could have been the case that when you were done with the solar system, you switched to nature or something, that there are several orbits, that you get on to nature or the sea or something. Or you can travel in time and stuff...

Even so, the avatar view was also the view that several children stated they would like to have more functionality. It was mentioned that they would like to be able to customize their avatar. The first participant stated:

"...I wish you could use what you have in your inventory..."

A second participant elaborated even more when asked what they disliked about the app, expressing the wish for customization:

"... When we finished a level, I got clothes for the avatar, but I kind of didn't get to change and stuff. I wish you could change your clothes..."

Another participant also added to this:

"...I thought the avatar page was cool, and I also liked the experiment site. But I want to do a little more with my avatar, color, clothes, and things like that...."

5.4.3 Informal Learning

Another theme emerged from the questions regarding the learning outcome of the app. There were different perceptions of how much the participants had learned through the experiments. When asked if they had learned anything while using the app, a participant mentioned one of the experiments as useful:

> *"... Yes. We did the invisible writing in the experiments, with lemon and stuff. So I feel like I learned a little bit in every experiment..."*

Another mentioned one of the other experiments:

> *"...Yes, you kind of learn why it happens and stuff. That experiment with eggs , you kind of understood why they were so strong and things like that. Yes, so you learn things from it..."*

Others expressed that they could not see the connection the experiments had with what they learned in science in school, and therefore they did not feel that the app had made them more interested in science:

> *"In a way not, because what we do in the app is not what we do in science class. If we could do experiments in science, it would be different."*

5.4.4 Design Suggestions

One of the questions asked was whether the children had any ideas which could have made the app better. The most mentioned aspects were game-based, including adding a battle pass, customizing the avatar, and giving the users greater leeway in choosing which experiments they would like to do. The first participant got asked whether they would like to have more games in the app:

> *"...It would be nice to have some games you could get points in, instead of just experiments. Like assignments you can do. Then you might get 100 points instead of 250..."*

When asked if the participant had any ideas to what could have made the app better, they suggested expanding the story with a good versus evil sort of gameplay:

> *"...Other missions and all that. Kind of like that, maybe you're going to try to get away from the astronaut if you're an alien. Also, you need to do missions to earn points. And maybe some game where you can shoot with spaceships at each other. That's a lot of good things. You can make aliens start from Neptune, the last planet, and the astronaut starts on Mercury to get to the sun and destroy it. So you play in the whole universe. The astronaut is going to destroy where alien lives in*

the Milky Way...."

One of the other participants expressed the wish for more customization in the app, adding different age groups and experiments to match the target group:

> *"...If there were age groups, you could choose how old you were when you entered the app because some of them are easier than others. Maybe choose what experiments you can do on each planet. I think it was a really cool app, I liked the design..."*

A third participant pointed out that the fewer words, the better, and preferred a drag and drop interface where they did not have to write so much themselves:

> *"...I like when you have a lot of words, and you should find the right word. It would be nice if you didn't have to write so much but instead press around...."*

The first participant also added that they would like the app to be adaptive so that the further the user got into the app, the more difficult it would be to move on. He also emphasized the importance of a battle pass, giving the user reward tiers:

> *"...Maybe if you'd done so that every time you came on a new planet, you'd need more points to move on. So you would have to do more experiments to move on. And maybe it could have been the case that you're leveling up. Do you know what battle pass is? Because if you have a battle pass like that, with cool characters and the app goes viral and does things and quizzes in the game and stuff like that, there are people who want to buy the battle pass and get other costumes and stuff. And if you have points so you can buy points to buy battle passes, you can make a lot of money..."*

Chapter 6

Discussion

This study has investigated how using an app with gamification elements can motivate children to learn science outside of school. Thus, the relevant findings from Chapter 5 will now be discussed in relation to answering the research question. The findings presented in Chapter 5 demonstrated some interesting factors which influenced children's motivation to use the app, and their learning outcomes. These factors were *autonomy*, *facilitation* and *flexibility and adaptiveness* and will no be discussed in regard to gamification elements, inquiry-based science learning, and informal learning to answer the research question *"How can the use of an app with gamification elements motivate children to learn science in an informal setting?"*.

6.1 Gamification Elements

When positioning the study after reviewing literature and getting insights from teachers, the goal was to create a prototype of an app that implemented gamification elements and aspects designed to engage the user's motivation, with elements such as avatars, progress, feedback, points, and a storyline. Based on the collected data, some of these elements were also found to be elements the children perceived as most motivating. In Table 5.2, one can see that the GM category had the highest minimum score in the data set, as well as a high mean value, which indicates that there was a joint agreement amongst the children in that gamification elements like points and storylines was highly motivating. There is also a strong significant positive correlation between EWU and GM in

Table 5.5. This implies that receiving points for completing experiments and following a storyline through the universe greatly affected the users' enjoyment and wish to use the app at school. Furthermore, it indicates that points and a clear storyline that allows the users to involve themselves in the app has potential for motivating the children to want to use it again. These findings are comparable to the studies done by Ding et al. [2017] and Hursen and Bas [2019], and indicates that even though points are seen as extrinsic motivators, they can also be seen as supportive elements which can facilitate learning. There was also found a significant negative correlation between age and GM, as seen in Table 5.6, which indicates that the younger the user, the more does gamification motivates in using the app. This is in line with the desire expressed in one of the interviews to have an app that is more flexible, presented in Subsection 5.4.4, so that it is possible to adapt the experience to the user.

In addition to storyline and points, the avatar view was one of the most influential in the app and the feature that most children would like to have had more functionality. There is conformity on this point in both the interviews and the log data, which indicates that having an avatar in the app can be an important element in motivating the children to use the app. As seen in Table 5.3, the avatar view had the second highest mean amongst the children, and is also the most frequent gamification element the interviewed children mentioned in Subsection 5.4.2. However, even though the interviewed children expressed that the avatar was what they liked the best with the app, they also wished for more customization. The findings regarding the wish for customization of the avatar also correspond with the heuristics constructed by Roy and Zaman [2017]. Making a system flexible by adding user characteristics aims to fulfill the basic psychological need for autonomy in regard to being motivated.

The *Battle Pass* was also a gamification feature mentioned as valuable in which the player saw their rewards as something to aim for. Although, this is not consistent with SDT, where intrinsic motivation is emphasized over extrinsic [Deci and Ryan, 2000]. The possible rewards are listed in the battle pass, which can act as a motivating factor for completing experiments. As seen through the children's use of the app, the battle pass both had advantages and disadvantages. When the app was demonstrated at school, some of the children asked if it was possible to click through the app without doing experiments, which they were told was possible. Some of the children would then complete the experiments without actually doing them. One reason for this may be that they wanted a gift card and therefore clicked through the app as proof that they had used it. Another reason may be that the extrinsic motivation that points and rewards gave was greater than the intrinsic motivation to do experiments. This was a risk that was necessary to take when testing it in an uncontrolled setting. To make the use of the app as realistic as possible, the children were not required to perform any experiments, although they were encouraged to do so. The results indicate that battle passes and points in the app have increased the user's motivation, but not necessarily the motivation towards actually completing experiments to learn. The fact that the child was allowed a high level of self-determination through using it in an informal setting without facilitation by guardians or teachers may have had an impact on how much learning benefit they got from using the app. It is not possible to conclude that the facilitation of parents or teachers would have impacted the benefits of the app. However, previous research by Clegg et al. [2006] and Gleason and Schauble [1999] indicates that parental involvement could be beneficial in assisting children's problem-solving process.

When asking for design implications and improvements to the app, the interviewed children were eager to provide solutions to create a motivational and fun app. One of the features mentioned was adding several different "worlds" to the gameplay. When finished with the solar system, the player would level up to a new game world with new challenges and experiments to solve. Furthermore, the children reported several design implications for a future app version. This included letting people choose experiments more freely, adding missions to the app, and expanding the story of one being an astronaut or alien who fights against the other by doing missions and gathering points. Storytelling is a great way for children to engage with the app, and a child can be featured as the main character of the story to make it more intriguing to them. These changes would be possible to implement in a future version of the app.

6.2 Inquiry-Based Science Learning

How to motivate children to learn in an informal setting? One of the most important ideas behind the app was that the children should use the app because they wanted to, rather than because they felt they needed to, as Deci and Ryan [2000] describe how the aspect of autonomy affects the inner motivation of the user. It is interesting to note that the app's innovative part was also one of the parts that the children pointed out as the best thing about it. The interviews showed that the combination of technology and real-life experiments motivated the children to use the app. These findings show similarity to the findings of the positive effects inquiry-based science learning has on children's motivation, where the child is engaged in their learning process [Havasy, 2001]. This can be attributed to the fact that since the child himself was free to decide when and how much to use the app, there were also no external expectations attached to its use, making it easier for the child to perceive it as fun rather than mandatory. However, the study conducted did not include interviews with all of the participants. Therefore, it is not possible to conclude the autonomy's effect on motivation, as insufficient quantitative data on this matter was gathered. Another consequence of the granted autonomy to use it as much or as little as they wanted, was that some informants did not use the app at all.

In Chapter 2, the studies of Havasy [2001]; Clegg et al. [2006] were presented, which emphasized the importance of revolutionizing the teaching of science. They mention the importance of including the children in the education and letting them explore by themselves as this would increase their motivation and interest in science. Their results are similar to the findings of this study, where children supported the combination of experimenting in a real-life environment with the use of technology. Several of the children confirmed that the one-sidedness of science education decreased their interest in science, where the majority of the education happens through direct instruction, as opposed to being inquiry-based.

Another interesting result from the interviews was that the children used the app when they were bored and wanted to do something other than just scroll on their phones. There was also suggested as an improvement that the user should have more autonomy in choosing which experiment they would want to do on each of the planets in the solar system, rather than having a fixed list of three experiments on each planet. The fact that the results show that the children wanted more autonomy and more challenges in the app substantiates the SDT and the heuristics of Roy and Zaman [2017] as seen in Table 2.1. These results are also consistent with the findings of Thomas and Müller [2014], which found that enhancing autonomy support in a system could increase the user's intrinsic motivation.

6.3 Connecting Informal and Formal Learning

In Table 5.5, there is a significant positive correlation between the LOA and the EWU. As the motivation to use the app increases, the children's perceived learning outcome also increases, which is in agreement with previous research, but not necessarily with the evidence from the interviews [Kalogiannakis et al., 2021]. In the interviews, several of the children expressed that they struggled to connect the learning outcome from the experiments with the curriculum in science, despite them enjoying the app.

As seen in Table 5.1, ATGS and ATE was the two variables that scored the highest mean values. The results indicate that the children had a high attitude towards using games in science education and perceived experiments as fun. This is consistent with a study done by Fortus [2014], which found that there is hard to learn without positive attitudes and engagement. Because motivation is what eventually leads to engagement, this is where one should start to lay a good foundation for learning. There was also a significant positive correlation between ATGS and EWU, as seen in Table 5.5, which is similar to the findings from Fortus [2014], that attitude affects enjoyment and motivation. Interestingly, when testing the children's attitude toward science before and after using the app and the perceived learning outcome of experiments before and after using the app, the learning outcome was significantly lower after using the app (see Table 5.7. It is possible that either the children failed to connect what they learned in the experiments to what they learned in science, or the experiments were not sufficiently related to the curriculum.

Although Clegg et al. [2006] stated that the combination of cooking and investigating scientific reactions was a good way of connecting learning to everyday life, there are found differences in this study. Children gave positive responses to the hands-on experiments, but they questioned whether they could relate the results to their science education. Many learners struggle to link what is learned in the classroom with what is learned outside of the classroom, as described by Fallik et al. [2013]. This suggests that the child needs support for transferring the knowledge they have learned between learning environments. It is also possible that the children would have benefited more from using the app in a more controlled setting, for example, in a science class, where they could have worked out hypotheses together.

The findings of this study show that gamification can motivate children in learning science in an informal setting if there is a more apparent connection between the informal and formal learning processes. Even though the children perceived the experiments as fun and the gamification elements as motivating factors in doing the experiments, they had difficulty connecting this to science learning. It is difficult to draw a conclusion on how much the children have learned through the app. To answer this, there would be necessary to do a more prolonged and more exhaustive study. Although, the children gave some implications for features that could help bridge this gap, which is possible to implement in a future solution. They suggested adding quizzes to the app, writing the hypothesis before conducting the experiment, and then writing what actually happened afterward.

6.4 Limitations

This thesis has contributed to a deeper understanding of how children interact with apps and gamification elements, how they are motivated to learn science through them, and how they view scientific experimentation. Furthermore, by assessing the limitations of this study, one can get an indication of the quality of the results.

6.4.1 Unforeseen Events

It is worth noting that the researcher of this thesis is not an experienced one; thus, the data collection and designing of the research have been affected. Working with children poses several challenges. Although the triangulation of the data had its advantages, it also presented challenges concerning the researcher's inexperience and the nature of children. The fact that the children should use the app at home was, on the one hand, important because the study was to test how children use a gamified app for learning outside of school. On the other hand, it posed a challenge because it meant that the study might not collect enough log data to be assumed valid. In retrospect, the creation of the questionnaire and interview questions would also have benefited from being worked through several times. Also, several questions should have been asked to gather more research-specific data. In addition, it was difficult to anticipate school and parent restrictions which made the actual testing of the app difficult. For a future study, it would have been useful to get familiarized with the rules and guidelines for this prior to developing and testing the app.

6.4.2 Reliability and Validity

The challenges discussed in Subsection 6.4.3 had some impact on the reliability and validity of the collected data. Initially, the plan was to recruit 40 participants for the study, but this proved to be difficult, both because it was challenging to recruit classes and schools where the app could be tested, and because of the technical problems, which led to even fewer participants in the study. In addition, the small sample size means that the significant reliability of the quantitative data is low, and the results should therefore be considered with this in mind.

6.4.3 Challenges During Development of the App

Despite the fact that development and designing went mostly according to plan, a few unpredictable problems occurred during the app's development and distribution. These challenges are described below.

As all of the children recruited through the convenience sampling had their own iPad at school, the intention was for them to receive a link to Apple's service for testing apps, called Testflight, and download the app before the demonstration of the app was to be carried out, so that they immediately could start using the app. However, only a few days prior to the intended user testing, the school informed that there was no possibility of downloading the app on the children's iPads due to the school's policy of restricted access to the App Store.

As a result of the app not being able to be downloaded on the childrens' iPad's, it was necessary to distribute the app to both Android and iOS devices for them to test at home. This included distributing the app to Google Play Store and Testflight and providing the children and parents with a guide on downloading the app's beta version on their devices. Due to the approval time of three-four business days for distributing the app for testers on the Google Play Store, there was minimal time to test the actual app before distributing it to the children. After distributing the app on Google Play Store and Testflight, the users with Android devices discovered a bug in the app where the experiments would not show. It turned out this flaw was not present before actually distributing the app, which led to even more delay in the user testing. As a result, the user testing period was extended for the Android users, and some of the iOS users. Some of the iOS users had parental restrictions on their devices which hindered them from testing the app. These events resulted in the sample size decreasing from 31 to 25 participants.

Chapter 7

Conclusion

The thesis investigated *how the use of an app with gamification elements can motivate children to learn science in an informal setting.* Based on a preliminary study and interviews with teachers, an app was designed in an iterative manner. Through interviews, questionnaires, and log data, it was possible to gather quantitative and qualitative data regarding children's attitudes, motivations, and perceptions of the gamification in the app.

The study's findings show that gamification holds promise for motivating children to learn science in an informal setting when there is a more obvious connection between the informal and formal learning processes. Despite the children's perception that the experiments were fun and the gamification elements such as storyline, points and avatar motivated them to do the experiments, they had difficulties connecting this to science learning. However, when the children gained self-determination over their own learning through the gamification elements in the app, their interest in science increased. The interviews also revealed that the children were motivated to use the app by the combination of technology and real-life experiments. Science becomes more tangible and engaging for children when it is inquiry-based, which makes experiments a good motivator in an otherwise theory-based subject, where students' attitudes are adverse. Learning requires balancing autonomy, freedom, and control, and guidelines should be established to achieve this balance. Due to the fact that the children were self-determined, the learning environment had an impact on the results as well. Therefore, it appears that the child needs facilitation when transferring knowledge between learning environments.

The results of this research can be summed up with three points on how gamification elements in an app can successfully motivate children to learn science in an informal setting:

- Enable users to determine when and where they would want to use the app
- Facilitate the children so that they can understand and transfer the knowledge into formal education
- Develop an adaptive and flexible solution by adding user characteristics to fulfill the need for autonomy, and letting the user experience increased challenge. (e.g avatar customization, missions, age groups)

7.1 Future Work

As a result of the findings and limitations of this study, new approaches to this problem arose. In the future, it would be beneficial to involve children in the design process to come up with a more suitable solution. Due to the short time frame and small sample size, as described in Section 6.4, it is difficult to draw a conclusion on how much the children have learned through the app. To answer this, there would be necessary to do a more prolonged and exhaustive study. The app can also be further improved by enhancing the balance of autonomy and control and by increasing the challenge in the app by adding missions, avatar characterization, and social interaction. Last but not least, the balance between autonomy, freedom, and control is an interesting approach that should be further investigated in relation to children.

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Appendices

Appendix A

Study

A.1 Consent scheme

Foreldresamtykke for barns deltakelse i forskningsprosjektet «*Experiverse*»

Hei! Jeg er en masterstudent ved NTNU i Trondheim, som lurer på om barnet ditt kan være interessert i å delta i et forskingsprosjekt? Jeg ønsker å finne ut;
«Hvordan kan spillifisering motivere barn til å lære naturfag i en uformell setting?»

Formål
Formålet med dette skjemaet er å gi deg (som forelder til en potensiell deltaker i forskningsstudien) informasjon som kan påvirke din beslutning om hvorvidt du vil la barnet ditt delta i et forskningsprosjekt hvor formålet er å kartlegge hvordan spillifisering (gamification) kan fungere som en motivator i naturfag utenfor skolen. Les informasjonen nedenfor og still eventuelle spørsmål du måtte ha før du bestemmer deg for om du vil gi barnet ditt tillatelse til å delta eller ikke. Hvis du bestemmer deg for å la barnet ditt delta i denne studien, vil dette skjemaet bli brukt til å registrere din tillatelse. Håper du og barnet ditt ønsker å være med! ☺

Hvem leder forskningsprosjektet?
Hanne Brynildsrud er masterstudent innenfor informatikk med spesialisering i interaksjonsdesign, spill- og læringsteknologi ved NTNU i Trondheim.

Hvorfor ønsker jeg at barnet ditt skal delta?
Grunnen til at jeg ønsker å ha med barnet ditt i forskningsprosjektet er at målgruppen for appen som utvikles er barn mellom 10-13 år. Jeg vet enda ikke hvem du er eller hva du heter, men din kontaktperson fra skolen gir deg dette brevet fra oss. Hvis du ønsker at barnet skal delta i prosjektet, må du skrive under på siste ark i brevet, og jeg vil kontakte deg. Dersom du ikke ønsker at barnet ditt skal delta, tar jeg ikke kontakt.

Introduksjon til appen

Experiverset er en mobil applikasjon med formål å fungere som en motivator innenfor naturfag og eksperimenter utenfor skolen. Dette gjennom eksperimenter som kan gjøres hvor barnet selv ønsker. Målet med appen er å lage seg en avatar i form av en astronaut og komme seg fra Merkur til Neptun i romskipet sitt gjennom å gjøre forskjellige eksperimenter på hver planet. På hvert eksperiment må barnet lage seg en hypotese om hva som kommer til å skje, gjennomføre det og svare på spørsmål i etterkant for å komme seg videre.

Hensikten med studiet
Hvis du samtykker, vil barnet ditt bli bedt om å delta i en forskningsstudie om hvordan spillifisering av naturvitenskap kan motivere barn til å lære utenom skolen. I sammenheng med dette har

det blitt utviklet en mobil app for å teste et realistisk scenario over hvordan spillifisering kan motivere barn innenfor naturvitenskap.

Hva betyr det for barnet å delta?
Dersom du lar barnet ditt delta i denne studien, vil jeg be barnet om å;

- Bruke appen Experiverse over en toukers periode og gjennomføre eksperimenter hjemme, ute eller hvor det er hensiktsmessig.
- Svare på en spørreundersøkelse angående deres motivasjon i naturfag, og om bruk av spillifisert læring og deres holdninger relatert til dette (f.eks. tilfredshet, letthet, vanskelige/lette/utfordrende deler av aktiviteten) både i forkant og etterkant av bruksperioden. Dette vil foregå på skolen.
- Barnet ditt kan også bli spurt om å delta i et kort intervju i etterkant av de to ukene som vil bli tatt opp på båndopptaker. Her vil det være snakk om opplysninger som hva de likte og mislikte ved appen, om de følte seg motivert osv. Dette vil også foregå i skoletid.

Dersom du som forelder ønsker å se spørreskjemaet eller intervjuguiden på forhånd, er det bare å ta kontakt.

Denne studien vil ta 2-3 uker og det vil være omtrent 40 andre barn i denne studien.
Data om deltakernes kjønn, alder og skoleklasse vil bli samlet inn ved hjelp av spørreskjemaene, og data lagret gjennom bruk av appen vil bli behandlet konfidensielt. Varigheten av brukertestingen vil vare omtrent 2-3 uker, bestående av de nevnte spørreundersøkelsene, brukertesting av systemet og et eventuelt oppfølgende intervju i etterkant av brukertesten.

Frivillig deltakelse
Det er frivillig å delta i prosjektet, og du eller barnet ditt kan når som helst velge å trekke sitt samtykke uten å oppgi noen grunn. Det betyr at det er lov å ombestemme seg, og det er helt i orden. All informasjon om deg og barnet vil da bli slettet.

Dine rettigheter
Deltakere har rett til å be om tilgang til/sletting/korrigering/begrensning av personopplysninger, rett til dataportabilitet (få utlevert personopplysninger om deg selv/barnet og gjenbruke dem som du vil på tvers av ulike systemer og tjenester), og rett til å sende klage til personvernombudet på NTNU eller Datatilsynet om behandling av personopplysninger.

Ditt personvern
Vi behandler opplysninger om ditt barn basert på ditt samtykke. Alle personopplysninger vil bli behandlet konfidensielt. Kun masterstudent og veileder vil ha tilgang til dataene (se generell informasjon under). Spørreundersøkelsene vil bli lagret i NTNU Sharepoint i henhold til databehandleravtalen mellom NTNU og Microsoft. Barnet må laste ned og lage en bruker i appen Experiverse med et brukernavn og passord for å kunne bruke den, som kun vil brukes i hensikt å kartlegge brukermønstre i appen. Det er viktig å nevne at deltakerne ikke vil være

gjenkjennelige i publikasjonen. Prosjektet er planlagt ferdigstilt innen starten av juni 2022, der alle data vil anonymiseres.

Studiet er varslet til NSD – Norsk senter for forskningsdata AS, som har vurdert at behandlingen av personopplysninger i dette prosjektet er i samsvar med personvernregelverket.

Generell informasjon
Dersom du har spørsmål angående prosjektet, ta kontakt med:
Hanne Brynildsrud, e-post: hannbry@stud.ntnu.no, mobilnummer: +47 46933108
Masterstudent ved Institutt for data- og informasjonsvitenskap ved NTNU

Veileder for prosjektet er Sofia Papavlasopoulou, førsteamanuensis ved Institutt for Data- og informasjonsvitenskap ved NTNU, e-post: spapav@ntnu.no, adresse: Sem Sælands vei 9, IT-bygget * 146.

Personvernombud ved NTNU (Thomas Helgesen, thomas.helgesen@ntnu.no)

Hvis du har spørsmål knyttet til NSD sin vurdering av prosjektet, kan du ta kontakt med:

- NSD – Norsk senter for forskningsdata AS på epost (personverntjenester@nsd.no) eller på telefon: 55 58 21 17.

Foreldresamtykke for barns deltakelse i forskning

Jeg har mottatt og lest informasjon om prosjektet Experiverse og samtykker til mitt barns deltakelse i forskningen.

Forelders navn: ____

____

(Signert av forelder, dato)

A.2 Interview guide

Interview guide qualitative interviews

Registration of responses
Notes and audio recordings will be taken during the interview. This allows the interviewer to gather important points of view, while at the same time ensuring that there is no information lost because the interviews have been recorded.

Create contact with attendee
Because the participants in the study will be children, it will be easier if they are comfortable opening up to the interviewer. To create a relaxed tone between the interviewer and interviewees, one can start the interview by asking non-research-related questions related to the child's hobbies, leisure time and so on.

Question structure
The questions shall be asked in such a way that the participant can give a detailed answer, instead of the participant only answering yes/no questions.

Examples of questions:

- Do you think Experiverse was fun to use? If that's the case, why/why not?
- What do you think was the best thing about the app?
- What do you think didn't work so well in the app?
- What do you think of science?
- Do you feel that doing experiments made you want to work more with science?
- Would you use the app again? If so, why?
- What do you think of the colors and animations in the app?
- What do you think about the journey in the app, that you should go from Mercury to Neptune by doing experiments?

These are just some examples of the type of questions that should be asked in the interview, but interviewers must also be prepared to follow up on answers, and possibly take new angles on the questions if needed.

Ending the interview:
Because the participants in the programme are children, it will be necessary to keep the interviews short, and interesting so that the child does not lose interest, and therefore one loses valuable point of view and feedback. Finally, it will also be a good idea to summarize what the participant has said and ask if there is anything else the child wants to add.

A.3 Pre-test questionnaire

Pretest Experiverse

Obligatoriske felter er merket med stjerne *

Innledende spørsmål

Hva er din e-postadresse? (Skole-epost) *

Hvor gammel er du? *

Hvilken klasse går du i? *

Kjønn *

- Jente
- Gutt
- Annet

Har du brukt spill til å lære før (Minecraft, Numetry, Roblox e.l.)? *

- Aldri
- 1-5 ganger
- 6-10 ganger
- 10 eller fler ganger

Svar på spørsmålene under ved å trykke på det tallet du synes stemmer best

Hvor gøy synes du naturfag er? *

kjedelig ... veldig gøy

1 2 3 4 5 6 7

Verdi

Hadde naturfag vært morsommere om dere hadde brukt mer spill i timen? *

uenig ... veldig enig

1 2 3 4 5 6 7

Verdi

Liker du å lære nye ting? *

ikke i det hele tatt ... elsker å lære nye ting!

1 2 3 4 5 6 7

Verdi

Synes du det er morsomt å gjøre eksperimenter? *

nei, det er kjedelig — **ja, det er kjempegøy**

1 2 3 4 5 6 7

Verdi

Lærer du noe av å gjøre eksperimenter? *

lærer ingenting — **lærer masse!**

1 2 3 4 5 6 7

Verdi

Send

A.4 Post-test questionnaire

Posttest Experiverse

Obligatoriske felter er merket med stjerne *

Info om deg

Hva er din e-postadresse? (Skole-epost) *

Hvor gammel er du? *

Hvilken klasse går du i? *

Kjønn? *

- ○ Jente
- ○ Gutt
- ○ Annet

Svar på spørsmålene under ved å trykke på det tallet du synes stemmer best

Hvordan synes du det har vært å bruke Experiverse? *

kjedelig — gøy

1 2 3 4 5 6 7

Verdi

Har det vært lett å bruke appen? *

vanskelig å bruke — lett å bruke

1 2 3 4 5 6 7

Verdi

Har du skjønt hva du skal gjøre i appen? *

nei, den har vært vanskelig å forstå — ja, det var lett å forstå

1 2 3 4 5 6 7

Verdi

Har du lært noe ved å bruke Experiverse? *

har ikke lært noe — har lært masse!

1 2 3 4 5 6 7

Verdi

Har du oppdaget noe nytt gjennom å bruke Experiverse? *

har ikke oppdaget noe nytt — har oppdaget masse nye ting

1 2 3 4 5 6 7

Verdi

Har du blitt mer eller mindre interessert i naturfag etter å ha gjort eksperimenter? *

mindre interessert — mer interessert

1 2 3 4 5 6 7

Verdi

Jeg synes det å gjøre eksperimenter i Experiverse har vært... *

vanskelig						enkelt
1	2	3	4	5	6	7

Verdi

Jeg synes det å få poeng for å gjøre eksperimenter i Experiverse har vært... *

kjedelig						motiverende
1	2	3	4	5	6	7

Verdi

Jeg synes det å reise gjennom solsystemet for å gjøre eksperimenter i Experiverse har vært... *

kjedelig						morsomt
1	2	3	4	5	6	7

Verdi

Etter å bruke Experiverse har jeg blitt... *

usikker på om jeg får til eksperimenter						sikker på at jeg får til eksperimenter
1	2	3	4	5	6	7

Verdi

Jeg skulle ønske vi kunne brukt Experiverse på skolen *

ikke i det hele tatt						veldig gjerne!
1	2	3	4	5	6	7

Verdi

Har du noe annet du vil si?

Appendix B

Development

B.1 User stories

USER STORIES
1 PROFILE & AUTHENTICATION
1.1 I want to be able to log in so that I can keep track of my progress
1.2 I want to be auto logged in when using the app, so that I dont have to log in all the time
1.3 I want to be able to verify my email address
1.4 I want to be able to change my profile
2 HOMEPAGE
2.1 Connect to database
2.2 I want to see which planet I am currently on to track my progress
2.3 I want to see how far I am from reaching the next planet
3 EXPERIMENTS
3.1 I want to see all of the experiments related to one planet
3.2 I want to see the steps for each experiment, and be able to cross off things I have done
3.3 I want to write an hypothesis and save it to each experiment
3.4 I want to see my progress on each experiment, or steps
3.5 Web crawling for experiments
4 AVATAR
4.1 I want to change my avatar
6 AVATAR ASSECORIES
6.1 I want to receive new asseccorize on each planet
7 ANALYTICS
7.1 I want to add analytics to the project
8 PUBLISH APP AND BUG FIXING

Appendix C

Results

C.1 Questionnaire descriptives

Descriptive Statistics					
	N	Minimum	Maximum	Mean	Std. Deviation
att_science	25	1	7	4,80	1,384
att_games_science	25	1	7	5,80	1,658
att_learning	25	3	7	5,48	1,262
exp_fun	25	3	7	5,80	1,225
learning_exp	25	3	7	5,12	1,269
use_fun	25	3	7	4,76	1,165
ease_of_use	25	1	7	5,32	1,376
understanding_use	25	3	7	6,20	1,190
learning_app	25	1	7	4,16	1,546
new_experience	25	1	7	4,16	1,908
att_science_after	25	2	7	5,08	1,412
ease_exp	25	3	7	4,84	0,987
points	25	4	7	5,56	1,044
story	25	4	7	5,32	0,988
confident_exp	25	3	7	5,40	1,155
wish_to_use	25	1	7	5,84	2,035
Valid N (listwise)	25				

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