Master's thesis

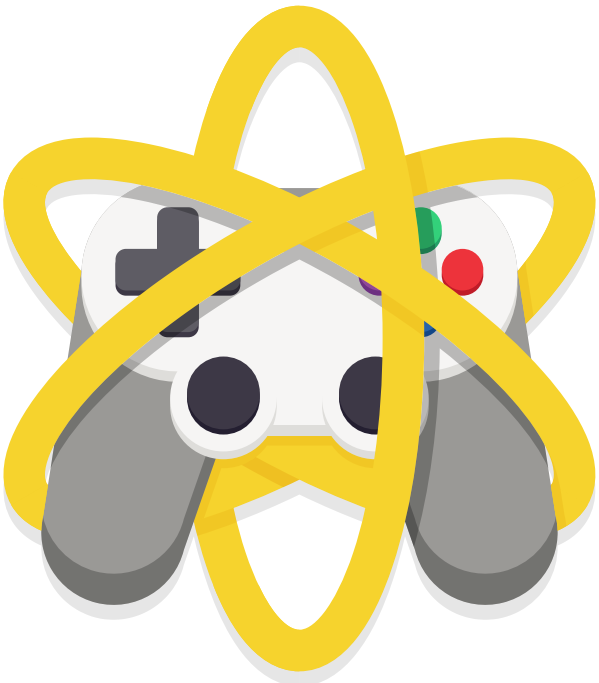
NTNU
Norwegian University of Science and Technology
Faculty of Information Technology and Electrical Engineering
Department of Computer Science

Andreas Naterstad Digernes
Einar Uvsløkk

Points of Science – Gamifying science activities out of school

An empirical study on game elements' effect on students' interest in and attitude towards science

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



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Abstract

Our society depends on informed citizens who have developed skills related to science, technology, engineering, and mathematics (STEM) in order to tackle global challenges. However, a major challenge is the decline in students' interest in STEM disciplines during their school years. In this thesis we present the development of a gamified mobile application that uses the game elements achievements, leader-board, points, and progress to engage students in out-of-school science activities. Gamification used in an out-of-school context is one piece in a bigger puzzle which can help increase their interest, aspirations, and involvement in STEM related aspects. The mobile application we present is grounded in a model of interest development, and is used to examine how the different game elements affect high school students' interest in and attitudes towards science. Moreover, we elaborate on the objectives, design decisions, and development of this application. We conducted a mixed design research experiment where 21 high-school students aged 18 to 19 years used the application over a period of four weeks. Quantitative data was collected from questionnaires pre and post experiment, as well as log and usage data from the application. Statistical analysis was performed on the collected data. The results show that the game elements do not affect students' interest in and attitude towards science, when comparing experimental and control conditions. However, results indicate that achievements and leader-board have such effects. The most significant effect on interest and attitude comes from intrinsic motivation for the individual game elements. Further studies should isolate the game elements in separate treatments, to measure their effect more precisely.

Sammendrag

Samfunnet er avhengig av å ha opplyste borgere med ferdigheter innen realfag for å kunne håndtere globale utfordringer. Én stor utfordring er imidlertid nedgangen i elevers interesse for realfag gjennom skoleløpet. I denne oppgaven presenterer vi utviklingen av en spillifisert mobilapplikasjon som bruker spillelementene prestasjoner, ledertavle, poeng og progresjon for å engasjere elever i realfagsaktiviteter utenfor skolen. Spillifisering er én brikke i et større puslespill som kan bidra til å øke elevenes interesse, ambisjoner og engasjement for realfag. Mobilapplikasjonen som presenteres er forankret i en modell for interesseutvikling og blir brukt til å undersøke hvordan de ulike spillelementene påvirker elevers interesse for og holdninger til realfag. Videre utdyper vi målsetningene, designbeslutningene og utviklingen av denne applikasjonen. Vi gjennomførte et eksperiment hvor 21 videregåendeelever i alderen 18 til 19 år brukte applikasjonen over fire uker. Kvantitative data ble samlet inn gjennom logg- og bruksdata fra applikasjonen, samt fra spørreskjema før og etter eksperimentet. Til å analysere dataene benyttet vi statistisk analyse. Resultatene viser at spillelementene ikke påvirker elevenes interesse for og holdningen til realfag når vi sammenligner resultatene fra eksperiment- og kontrollgruppen. Derimot indikerer de spesifikke resultatene for prestasjoner og ledertavle at disse har en slik påvirkning. Den mest signifikante påvirkningen på interesse og holdning kommer fra elevenes indre motivasjon for de enkelte spillelementene. Fremtidige studier anbefales å isolere spillelementene i større grad for å måle deres påvirkning mer presist.

Acknowledgements

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Furthermore, we would like to thank Eva Morken Endresen at Amalie Skram videregående skole in Bergen for being at our disposal when we needed it the most during the recruitment phase. She gave us an opportunity and provided us with a valuable contribution to conduct the experiment for this thesis. We also thank all the students at Amalie Skram videregående skole who willingly spent part of their own spare time participating in our research project.

Finally, we would like to thank our fellow students for their social and academic input, as well as our friends and family for their moral support and for spending precious time proofreading this thesis.

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Abbreviations

API application programming interface 20, 21, 58, 61–63, 69, 70

Cedefop European Centre for the Development of Vocational Training 8

EAS Expo Application Services 21

GUI graphical user interface 57, 59, 61, 63, 70

IMI intrinsic motivation inventory 27, 28

NSD Norwegian centre for research data 25

OECD Organisation for Economic Co-operation and Development 8

REST representational state transfer 70

STEM science, technology, engineering, and mathematics 1, 10, 13, 17, 22, 39

UI user interface 21

UML Unified Modeling Language 19

1 Introduction

This chapter introduces the research done for this thesis. The chapter is divided into four section. It starts by describing what motivated the thesis, and continues with a description of the problem it tries to solve. Here the research question for the thesis is presented with a description of how it will be answered. An overview of the approach for the thesis then follows, before the chapter is concluded with an outline for the rest of the thesis.

1.1 Motivation

Nowadays, our world faces global challenges that range widely from refugees, famine and access to water, to climate change and economic inequality [1–3]. It is becoming more important than ever that today's youth is adequately prepared to bring knowledge and skills to solve problems, make sense of information, and know how to gather and evaluate evidence to make decisions. These are the kinds of skills that young students develop in science, technology, engineering, and mathematics (STEM) disciplines, which will also help them to grow into critical citizens able to shape their own future [4–7]. Several studies have investigated how problem-solving and exploratory learning have been used to teach STEM in out-of-school contexts, with the use of technological affordances coming from the use of personal devices, gamification, and game-based learning [8–10]. In relevant studies students learned STEM skills, establishing inquiry questions and hypotheses and gathering evidence to support them. This is a challenging task, as students tend to find it difficulty to propose and justify scientific arguments [11]. It is therefore useful for students to learn how scientific claims are made, how they are backed, and what evidence they are supported by [12]. Choi *et al.* [13] argued that construction of arguments is an ability that can be improved over time and that maturity is not essential to learn such a skill.

A cause for concern that has been observed during the last years is students' decline in interest in STEM related subjects during their school years [14]. Gaining knowledge and skills in STEM related domains is important for many reasons, including critical thinking which is a catalyst for innovation and a vital factor in assisting problem-solving and exploratory learning needed to become a critical citizen in our societies. Therefore, a decline in interest in STEM is alarming because interest is one of the drivers for peoples future studies and career choices [15–17].

Loss of interest does not mean it ceases to exist, but is something that can be triggered at any time [15]. However, maintaining and developing interest requires re-engagement

with content over time. Gamification is a concept which have been proven to both motivate and increase user activity [18–20], as well as make users reengage with content over a longer period of time [19]. There are also studies that indicate that gamified applications can trigger and increase interest [9, 10, 21]. These studies show that applying game elements to applications in an out of school context can be an effective way of both teaching and increasing students' interest in science and their science capital. As students spend most of their time on informal activities outside of school, the impact these activities may have on students' learning is profound [22].

1.2 Problem description

Previous studies have shown that gamification can both motivate and increase user activity [18–20], and there is evidence that game elements can be used to increase interest [8–10]. However, problems with the state of current research on gamification include (i) a lack of theoretical foundation to explain motivational effects, and (ii) treating gamification as a general concept [23].

The aim of this thesis is to look at how specific game elements — achievements, leader-board, points, and progress — can be used in a gamified mobile application to affect students' interest in and attitude towards science. The thesis will specifically look at the effect of gamification of informal learning activities out of school. The research question of the thesis is formulated as follows:

RQ. *How does the use of game elements in informal science activities affect young adults' interest in and attitude towards science, in the context of a mobile application?*

Establishing boundaries for our research question through hypotheses helps us clarify the details of what this study want to investigate. The hypotheses will help us answer our research question in a structured manner and is formulated as follows:

H1. Students exposed to game elements in the application had a significant increase in their interest for science.

- **H1a**. Students exposed to the game element *achievement* had a significant increase in their interest for science.
- **H1b**. Students exposed to the game element *leader-board* had a significant increase in their interest for science.
- **H1c**. Students exposed to the game element *progress* had a significant increase in their interest for science.
- **H1d**. Students exposed to the game element *points* had a significant increase in their interest for science.

H2. Students exposed to game elements in the application had a significantly stronger positive attitude towards science.

H2a. Students exposed to the game element *achievement* had a significantly stronger positive attitude towards science.

H2b. Students exposed to the game element *leader-board* had a significantly stronger positive attitude towards science.

H2c. Students exposed to the game element *progress* had a significantly stronger positive attitude towards science.

H2d. Students exposed to the game element *points* had a significantly stronger positive attitude towards science.

The relevance of this problem lies in the fact that the development of interest in science can contribute to a change in attitude [9, 10, 21]. According to Bandura [24] a change in attitude can reduce the perceived difficulty of a task. Thus, by changing peoples attitude towards science the perceived difficulty of proposing, justifying, and understanding scientific arguments might be reduced. There are several science applications that have made construction of scientific arguments engaging, and have shown that interest can be increased and attitudes can be changed [9, 10]. To the best of our knowledge the effect game elements have on interest in and attitude towards science have not been investigated. This thesis will contribute with a gamified mobile application that aims to affect users' interest in and attitude towards science. This contribution extend the research conducted by Bressler *et al.* [10] and Smith [25], and will specifically investigate the effect of points, leader-board, achievements, progress, and challenges. Insights into whether these game elements contribute to increased interest and change of attitude will be provided.

To answer our research question we have conducted an experiment on Norwegian high school students. We have designed and implemented a gamified mobile application, which have been used in the experiment. The application provided participants with an out-of-school learning environment, where they completed various science related challenges. Questionnaires have been used to collect data at the start and end of the experiment. While participants used the application, we also collected usage statistics from each participant.

1.3 Approach

The approach to this thesis have been carried out in phases as described in Table 1.1.

Table 1.1: Phases of the work carried out as part of the thesis.

Phase	Description
Literature review	A review of the literature in the domain of gamification and learning was conducted to identify what have already been studied, what is missing in the research, and finally help define the problem description and research question for the thesis.
System design	Based on theories from the literature review and inspiration from related work and existing solutions, a system design for the application developed for this thesis was conceptualized.
Research design	The research design for the empirical study was planned in parallel with the system design. Research methods were chosen to both utilize and propose new system functions.
System development	The application conceptualized during the system design phase was implemented and tested.
Empirical study	The mobile application developed for this thesis was used in the empirical study for the thesis. The empirical study was conducted in the form of an experiment on Norwegian high school students.
Data analysis	The data collected in the empirical study was analyzed to provide empirical findings. The findings was used to answer the research question of the thesis.

1.4 Thesis outline

The rest of the thesis is outlined as described in Table 1.2.

Table 1.2: Outline for the rest of the thesis.

Chapter		Description
2	Background	Provides definitions of key concepts and presents relevant theories, related work, and existing solutions from the literature review.
3	Design and implementation	Elaborates on design decisions and implementation details of the mobile application developed for the thesis.
4	Methodology	Describes the methodology and the procedures of the empirical study.
5	Results	Presents results and findings from the analysis of the empirical study.
6	Discussion	Discusses the results and findings from the empirical study.
7	Conclusion	Concludes the work done for the thesis, elaborates on the limitations of the study, and proposes future work to be carried out.

2 Background

This chapter presents relevant theory and related work for the thesis. The chapter is divided into five sections. First a description of the literature search is presented, followed by definitions of concepts and terms. Then relevant theory and related work are discussed, before existing solutions are presented. At last a summary is given that concludes the chapter.

2.1 Literature search strategy

There are four main topics this thesis revolves around — gamification, learning, interest in science, and attitude towards science. The search for literature began broadly with the aim to acquire knowledge about the use of gamification in a learning context. Various search strings, such as "*gamification AND ((out-of-school OR non-formal OR informal) AND learning)*", were used to search for papers in Google Scholar and Oria. This resulted in a selection of relevant literature studies on gamification, which revealed relevant concepts within the field of psychology. The new knowledge was used to create more targeted search strings that focused on psychological outcomes and behavioral change. Examples of such search strings include "*gamification AND 'motivational affordance'*" and "*gamification AND self-efficacy*". The literature search was wrapped up by including topics from our problem description in conjunction with other discovered topics. The literature search resulted in papers that helped define our research question. More papers were included in the final list by following citations in these papers.

2.2 Definitions

In this section, definitions of concepts and terms relevant to the thesis are presented.

2.2.1 Gamification

Gamification describes applications using game elements matching given characteristics from games. Gamification is defined as *"the use of game design elements in non-game contexts"* [26, p. 10]. Which game elements are needed to make up a game is not clearly defined. According to Deterding *et al.*, gamification does not require an application to be a full game, only the use of game elements are needed [26]. Game elements are referred to as motivational affordances in the literature addressing gamification. Motivational

affordances refer to an object's properties; how these properties express the object's use cases and how it supports the user's motivational needs [27]. A large variety of different game elements have been used and the most common once are points, leader-boards, and achievements [28]. Motivational affordances can affect the psychological outcome for a user of a gamified application, and as a result, cause a behavioral change [27, 29, 30].

2.2.2 Formal, non-formal, and informal learning

The notion to distinguish between formal and other types of learning is nothing new. Already in the late 1960s, in connection with "the world educational crisis", Coombs [31] argued for placing greater emphasis on non-formal education as a complement to formal education. Later, in the mid 1970s, Coombs and Ahmed [32] found it useful to also include the concept of informal learning. Formal, non-formal, and informal learning thus forms a tripartite categorization of learning that is well grounded in the literature [32–35]. All of which are recognized by both the Organisation for Economic Co-operation and Development (OECD) [36] and the European Centre for the Development of Vocational Training (Cedefop). Cedefop gives the following definitions [see 37, Annex 1]:

formal learning *"learning that occurs in an organised and structured environment (e.g. in an education or training institution or on the job) and is explicitly designated as learning (in terms of objectives, time or resources). Formal learning is intentional from the learner's point of view. It typically leads to validation and certification."*

non-formal learning *"learning which is embedded in planned activities not always explicitly designated as learning (in terms of learning objectives, learning time or learning support), but which contain an important learning element. Non-formal learning is intentional from the learner's point of view."*

informal learning *"learning resulting from daily activities related to work, family or leisure. It is not organised or structured in terms of objectives, time or learning support. Informal learning is mostly unintentional from the learner's perspective."*

The types of learning defined above tends to overlap to some extent when it comes to where the learning takes place (e.g., in and out of school). In this thesis, the focus will be on learning that takes place outside of school, and will include a cross between non-formal and informal activities.

2.2.3 Interest

Interest is a psychological state with different phases of development, which impacts an individual's willingness to reengage with learning content [15]. Interest includes both an affective and a cognitive component that are separated, but which interacts with

each other. The affective component is connected to the positive emotions triggered by engagement. The cognitive component on the other hand is related to engagement by interpretation through senses and representational activities. Interest is associated with a highly positive affective character, but can also be triggered by negative situations.

The two main types of interest are situational and individual interest [15]. Situational interest is invoked by actions or content in the environment. It is triggered suddenly and last for a short period of time. In the context of reading, situational interest has been found to have an effect on attitude [38]. Individual interest is how an specific interest is developed within a person and contributes to cognitive performance. This type of interest develops slowly, could have a long lasting effect, and affects a person's knowledge and values [39]. In general, situational and individual interest describe two different ways of how interest can be generated.

2.2.4 Attitude

Sarnoff defines attitude as *"a disposition to react favorably or unfavorably to a class of objects"* [40, p. 261]. This definition explains how a person react, positively or negatively, towards objects triggering attitude. Objects can be physical, environmental, situational or mental. Reactions from attitude could be expressed by body language, behavior, expressions, and verbal formulations [40]. It is important to point out that even though it exists definitions for attitude, it is no consensus for a single definition within psychology [41, pp. 361–362].

2.2.5 Extrinsic and intrinsic motivation

Motivation comprises the factors that initiate and control human behavior. According to self-determination theory [see 42] motivation may be either extrinsic or intrinsic, depending on the reasons that give rise to an action [43]. Extrinsic motivation is referred to as *"the performance of an activity in order to attain some separable outcome"*, while intrinsic motivation refers to *"doing an activity for the inherent satisfaction of the activity it self"* [44, p. 71]. Extrinsic motivation have traditionally been viewed as pale and impoverished, compared to intrinsic motivation in terms of learning quality and creativity. But even though research have shown intrinsic motivation to be superior to extrinsic motivation in terms of learning [42, p. 248], it is worth noting that most activities people do are in fact extrinsically motivated [43].

2.2.6 Self-efficacy

According to Bandura self-efficacy is defined as *"people's beliefs in their capabilities to produce given attainments"* [45, p. 307], which states how a person's confident in their own skill will affect the initiation and the persistence of actions taken to handle situations. As a result people will avoid situations or activities which they believe they are not capable or have the necessary skill to handle. If success is expected or is what is believed to be

the outcome, then it will affect the effort people is willing to put into the obstacles they face and to persist longer to tackle the challenge. By persisting longer with challenges that subjectively feels threatening or unknown, can trigger a mental correction of the defensive behavior towards an obstacle which reinforces a person's self-efficacy [24].

2.2.7 Science capital index

Science capital is a framework that captures what you *know*, what you *think*, what you *do*, and *who* you know – in the context of science, technology, engineering, and mathematics (STEM) [46, 47]. The science capital index is a measure of peoples scientific literacy, their confidence in skills and abilities, their engagement in science activities, and their social network with science-related jobs [48]. Individuals with high science capital are more likely to study science in the future. On the other hand, individuals with low science capital are less likely to do so as they find it difficulty to engage with the subject.

2.3 Related work

Gamification emerged as a buzzword in the business and marketing sectors about ten years ago [49, 50]. Data from Google Trends shows that the interest in gamification has increased rapidly since the end of 2010 (Figure 2.1). Likewise, data from Web of Science show that the number of academic publications related to gamification has seen a similar development (Figure 2.2). According to Deterding [49] the rise of interest in gamification can be attributed to a number of converging factors: access to cheap tracking technology, increased tracking of personal data, and the cultural momentum of video games.

In the following sections findings from works relevant to this thesis are discussed. The discussion will follow the concepts listed in Table 2.1, which also serves as an overview of the most important papers identified.

Table 2.1: Concept matrix for papers covering related works.

Paper	Concepts				
	Gamification	Interest & Attitude	Motivation	Self-efficacy	Non-formal or informal learning
Shores and Shannon [51]	×		×	×	
Goldman *et al.* [9]		×			×
Fitz-Walter *et al.* [52]	×				×
Smith and Baker [53]					×
Banfield and Wilkerson [54]	×		×		
Janis *et al.* [8]	×	×			×
Sailer *et al.* [23]	×		×		×
De Troyer *et al.* [55]	×				×
Bressler *et al.* [10]		×			×
Ng and Chu [56]			×	×	×

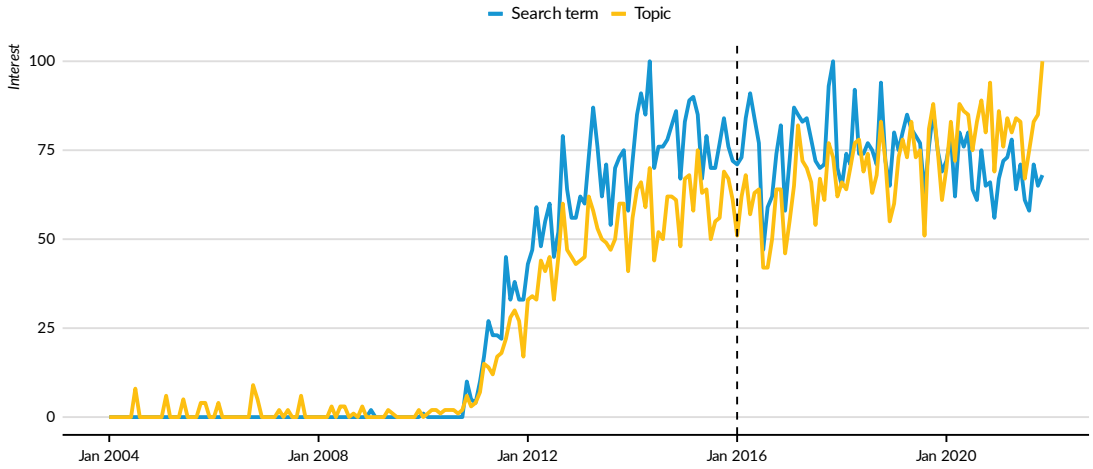


Figure 2.1: Interest over time for "gamification" as search term and topic. Numbers represent search interest relative to the highest point on the chart for the given month. A value of 100 is the peak popularity for the term, while a value of 50 means that the term is half as popular. The vertical dashed line indicates when Google applied an improvement to their data collection system on Jan 1, 2016.

Source: Google Trends

2.3.1 Science capital and attitude

Several studies have pointed out a correlation between science capital and self-efficacy and that more science capital results in higher self-efficacy [48, 57]. In a review of 17 studies addressing attitudes towards statistics, 15 of the studies found that students with previous experience or better achievement in statistics, had stronger positive attitudes [58]. The same observation is made by Christidou *et al.* [57] during coding workshops with children. The expectancy-value theory divide attitude into (i) *affect*; how much you like something, (ii) *interest*; how interested you are, (iii) *cognitive competence*; perception of own abilities, (iv) *difficulty*; how challenging they perceive something, (v) *effort*; how much time and resources must be put into a task to accomplish the task, and (vi) *value*; the importance and usefulness of the task for the student [59].

The expectancy-value theory establish a theoretical relationship between attitude and its components, which means that a change in one of the components can lead to a change in attitude. There are studies that indicates that attitude can also affect its components [58]. The majority of the studies demonstrated that positive attitude led to better performance and negative attitude led to the opposite. It is proven from several studies that science capital correlate with self-efficacy [48, 57]. As a result, since self-efficacy is a component of attitude, science capital can prove to be a useful metric to understand students' attitudes. We will use science capital, as stated by Christidou *et al.* [57], to capture students' experiences with science learning.

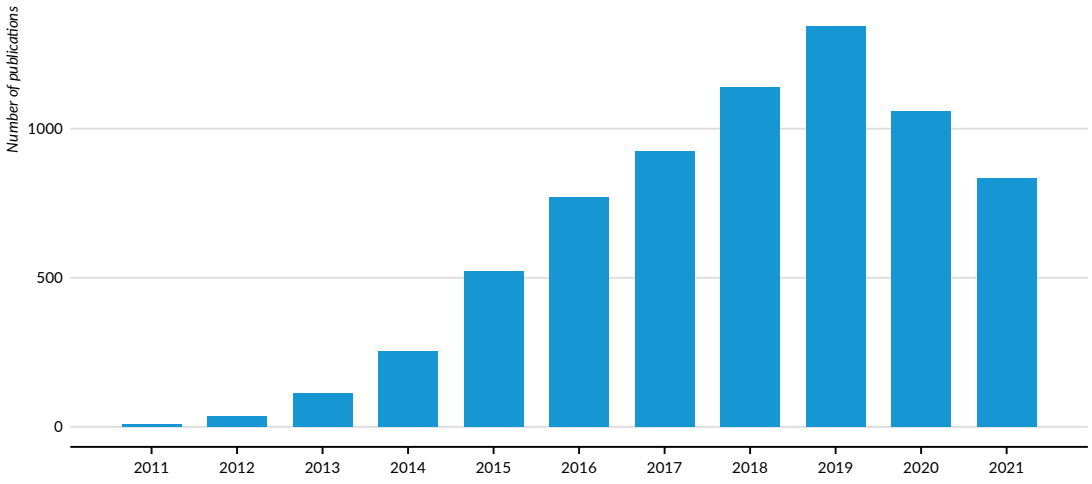


Figure 2.2: Publications per year matching the keyword "gamification" in the Web of Science Core Collection.

Source: Web of Science

2.3.2 Interest and attitude towards science

Situational interest is the initial step towards a well-developed individual interest, and can be triggered by exposure to activities or content [15]. If the content triggers a positive effect, a person may be willing to finish a task. A negative effect may cause the situational interest to fade. Given that the positive feeling lasts, and the person sees value in the content, reengaging with the content over time is needed for initial interest to develop into a maintained situational interest. For further development, the environment must support people in linking related content, so that they understand the value of their new knowledge [15]. Persisting interest causes individual interest to emerge. At this stage, creation of activities and formulation of questions related to the content are proposed by individuals themselves. As a result, intrinsic motivation drives the continuous exploration of the content. This is because individual interest and intrinsic motivation describes the same outcome, but in their own respective ways. Individual interest is an outcome of the relation between someone and some content, while intrinsic motivation is an outcome of human behavior unfolding in the moment and over time [60]. They are related through the amount of time invested in some content and the impact this have on behavior. Sustained exposure causes individual interest to develop into a well-developed individual interest, as described by Hidi and Renninger [15] in the four-phase model of interest development. The individual will do the same activities, but are more capable of overcoming frustrations when challenges related to the content arise.

A gamified digital platform was developed by Janis *et al.* [8] to collect and visualize

data from an oyster restoration project at the New York Harbour. The project lasted for three years and involved 80 teachers and 8640 students. Findings from the study showed that students involved in the project maintained their excitement over time. Students also became more curious about the activity when the teacher provided support. Moreover, the study found that visualization of data in the platform encouraged the students to propose research inquiries on the data collected, search for answers, and seek evidence for their hypotheses. The trigger of situational interest was the content itself (i.e., oyster restoration) and the gamified platform was a secondary tool contributing to the development of interest. The implications the paper has on the research question of this thesis is an indication that out of school activities can trigger situational interest. The interest could then further develop into a well-developed personal interest due to the content and the activity on its own.

Goldman *et al.* [9] conducted a summative evaluation of WolfQuest, an educational video game teaching youths about wolves, and found evidence that the game increase interest and reinforces positive attitude towards wolves. It changed the participants behavior related to conservation of wolves in a positive way, and it made the participants formulate scientific questions and use scientific methods to find answers to the question asked. The evidence indicates that the game-based learning application could trigger and develop interest with its content. In a study conducted by Bressler *et al.* [10], evidence was found that situational interest correlates with flow. The study investigated the use of a game-base learning application and found that situational interest could be triggered by application elements that promoted flow. A limitation of the study is that it present no evidence that flow causes interest. Bressler *et al.* therefore propose to investigate if game elements is what causes the triggered interest towards the content.

2.3.3 Motivation and self-efficacy

According to Sailer *et al.* the main aim of gamification is *"to foster human motivation and performance in regard to a given activity"* [23, p. 371]. By introducing gamification in a post secondary information assurance course, Banfield and Wilkerson [54] found a dramatic increase in intrinsic motivation in participants, while in a survey conducted on fifth- and sixth-grade students in a mathematics course, Shores and Shannon [51] found a significant correlation between intrinsic motivation and self-efficacy. In another study Ng and Chu used out-of-school flight simulation activities to motivate students to learn STEM. By examining the relation between four constructs of motivation — self-efficacy, peer learning, and intrinsic and extrinsic motivation — they found a positive correlation between all of them. They also found that participants were most strongly motivated by peer support, followed by intrinsic motivation, and least by self-efficacy.

Although the majority of studies on gamification indicate positive effects on motivation, Sailer *et al.* pinpoints two problems with the state of current research on gamification: a lack of theoretical foundation to explain motivational effects, and treating gamification as a general concept [23, p. 372]. In a simulation study on the effect of

specific game elements, Sailer *et al.* applied the theory of self-determination [see 42] to explain the motivational power of gamification. The result from the study indicate that gamification can be a successful tool in addressing motivational challenges in learning. But, as Sailer *et al.* puts it, the gamification must be *"well designed and built upon well-established implementation models"* [23, p. 378].

To explain how gamification affects the learning outcome in different contexts, Landers [61] has introduced the theory of gamified learning. The processes of *moderation* and *mediation* forms the foundation of the theory. Gamification via moderation affects learning by improving the learning content. Gamification via mediation, on the other hand, affects learning by encouraging a change in behavior or attitude in participants. That is, the change in behavior or attitude itself will improve the learning outcome. An example that Landers uses to illustrate the difference between these processes is the use of a narrative. To increase student motivation, one might add a narrative to an existing learning plan. The same narrative can then be used to increase the time students spend at home with the learning material. Landers also stress that the outcome of gamification (i.e., attitude and behavior) must be measured explicitly [61, 62].

2.4 Existing solutions

Many applications have been developed and tested that address similar challenges as this thesis. In the following sections, the most relevant existing solutions will be discussed.

2.4.1 Wolf Quest

Wolf Quest is an educational video game used to teach youths about wolfs, their habitats and how wolfs survive and reproduce. It was developed by Educational Web Adventures and used in a study conducted by Goldman *et al.* [9]. The purpose was to investigate if game-based learning could be used to increase the knowledge of, interest in, and attitudes towards wolves. It is a computer game with a supporting website presenting information about wolves. The website has a forum where the community can discuss the game and share ideas. The users play as a wolf avatar in an open world with a narrative of helping the wolf to survive. Players must evolve strategies for hunting, understand how a wolf pack cooperate, and how to dispose energy for different activities. Other things players can do is complete missions, interact with others and the environment. The curriculum is not explicitly taught, but woven into the game mechanics. Their findings showed that the participants increased their understanding of wolves by being able to point out what they had learned. They also found that the interest towards wolfs transferred into a change in behavior and attitude by using external sources for information about wolves. By analyzing forum posts they also found evidence for use of scientific methods such as model-based testing, social construction of knowledge, and problem-solving.

2.4.2 TICKLE

TICKLE is a digital playful learning environment for stimulating youngsters to explore their environment. It was developed by De Troyer *et al.* [55] to tackle school burnout and hinder early school leave among youngsters in Flanders, Belgium. While the initial focus was on informal learning, the focus was broadened to include both non-formal and formal learning as well. It is implemented as a smartphone application using persuasive technology and game elements to induce a behavioral change among youngsters with school burnout. The application uses cards to provide learning activities in the form of location-based challenges. Users get points by collecting cards, i.e., completing challenges. User feedback is implemented as a persuasive notification system, with messages tailored towards the personality of youngsters. De Troyer *et al.* conducted several formative evaluations of the application, and found indications that it may be able to increase both intrinsic motivation and learning capacity of youngsters. However, more summative and longitudinal evaluations are needed to confirm these results [55].

2.4.3 School Scene Investigators

School Scene Investigators is a forensic science game developed for middle school students by Bressler *et al.* [10]. The game is implemented as a series of mystery cases where students explore their school in search for clues and evidence needed to solve a specific mystery case. Students collaborate in teams by solving puzzles and piecing together evidence. The game is designed for mobile devices and uses augmented reality to enhance players' game experience. The aim of the game is to engage students by promoting flow and trigger their interest toward science. According to their findings, students playing the game reported both high flow and triggered interest. The presence of triggered interest is valuable because it means that the interest have the potential to evolve into a more long-lasting well-developed individual interest [10].

2.4.4 Billion Oyster Project

The Billion Oyster Project is an informal field trip to restore oysters in New York Harbour [8]. It teaches middle-school students how they can help to restore and monitor their local marine life through scientific learning. As a part of the project a digital platform was developed. The digital platform supports the project by facilitating data collection, recording and uploading of manual and live stream input. It provides tools for monitoring the oysters and analysis of data, as well as media archive and gamification. The students takes notes when collecting data during the field trips to the harbour, which they input to the platform afterwards. The platform then visualize the data, encouraging the students to ask scientific inquiries they must back up with evidence to support their hypothesis. An incentive structure for participation, with points, rewards and badges, are integrated into the platform. Analytics is also a part of the platform to capture all participants types of motivation for using it.

2.4.5 LibraryCraft

Smith and Baker [53] conducted a study on a library orientation game called LibraryCraft. The goal was to assess its effectiveness of teaching students about the library's services. The purpose of LibraryCraft was to guide students' through the library's website and online services such that students become more familiar with those services. The game presents the user with a story and a narrative set to the medieval age. The players can choose an avatar to represent them in the game. Through out the game, players' must do tasks like looking up books or answering questions about library services. To motivate the students the tasks becomes progressively more difficulty. The game uses a reward system by making the players have to unlock new chapters by entering correct answers to the task. Smith and Baker found that the game teaches the students new library skills, indication that the difficulty level was balanced, and that the story and narrative made the game fun to play.

2.4.6 Orientation Passport

Orientation Passport is a mobile application utilizing an achievement system to help and engage new students at university orientation [52]. It is implemented as a digital orientation schedule and includes a customized list of events, an interactive campus map, an information page, a friend page, and a profile page. Achievements are unlocked by completing tasks with varying degree of difficulty, e.g., adding a new friend to your contacts or scanning the catalogue code of a book at the library. The application was used in a case study conducted on students at the Queensland University of Technology, in Brisbane Australia. Findings from the study indicate that game elements like achievements can add positive value to an application, but that great care must be put on the balance between usability and enjoyment.

2.5 Summary

In this chapter key definitions relevant to the thesis have been established. Furthermore, a thorough review of related work have been conducted and the state-of-the art have been presented. The chapter have identified shortcomings with the current research on gamification [23], found applicable motivational theories [24, 42] and a model for describing development of interest [15]. Several gamified and game-based learning applications [8–10] have provided insight into how out-of-school activities can be used to increase interest and self-efficacy, and change attitude.

In this thesis the self-determination theory of Deci and Ryan [42] will be used as the foundation to explain motivational effects in the empirical study of this thesis. The four-phase model of interest development [15] will be used to drive the design decisions in the design and development of a gamified mobile application.

3 Design and implementation

This chapter presents the mobile application *Points of Science* developed as part of this thesis. The chapter is divided into four sections. It starts with presenting the objectives of the application, followed by a description of the development steps for the application. A description of tools and technologies used for the implementation are then provided, before the chapter is concluded by elaborating on the design decisions.

Initial wireframes for the application can be seen in Appendix A, and a more detailed description of the system architecture is provided in Appendix B. The source code of the *Points of Science* application is made available under a MIT license, and can be obtained from github.com/einaru/points-of-science.

3.1 Application objectives

We have designed and developed a gamified mobile application that aims to attract high school students to engage with science related learning activities in out-of-school contexts. The main objective of the application is to increase student's interest in and positive attitudes towards science. This is achieved by providing an engaging experience that increases their science capital (i.e., what you *know*, what you *think*, what you *do*, and *who* you know – all in the context of STEM). The main characteristics and goals of the application is to enable students to:

- investigate different science topics,
- choose challenges matching their skill level,
- reflect on the learning outcome from a challenge,
- seek external sources for information and explanations,
- be curious and exploratory,
- conduct their own scientific inquiries, and
- better understand scientific methods and procedures.

The overall goal of this project is to test the application with users through an empirical study and map the effect that different game elements may have on the development of students' interest and attitudes. To do so, the project is grounded in the four-phase model of interest development [15]. With this regard, the design of the application has been influenced by this model. Figure 3.1 illustrates that users have an initial interest for, attitude towards, and self-efficacy in science, and how the application initiates and drives the four phases of interest: (i) situational interest, (ii) maintained situational

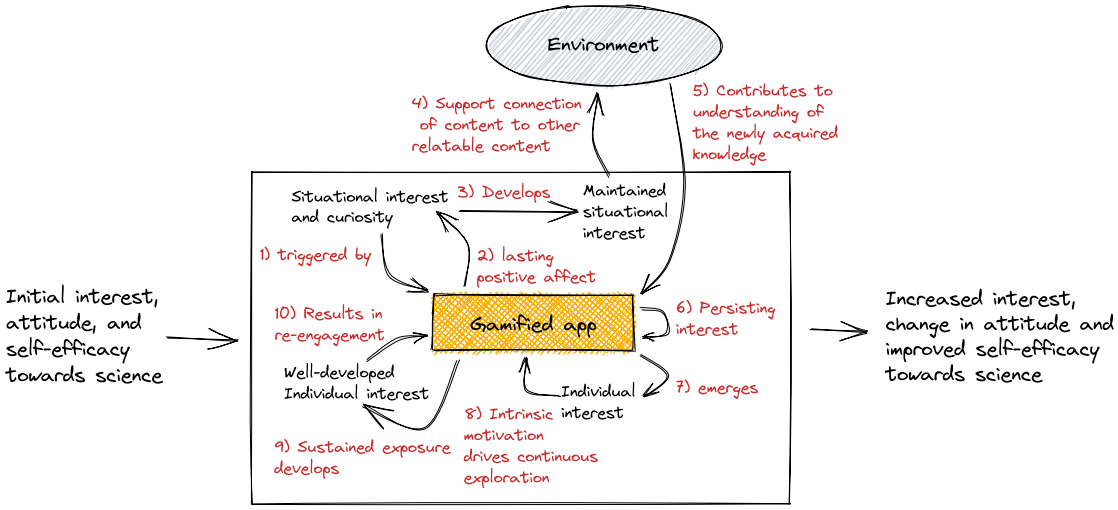


Figure 3.1: Applying the four-phase model of interest development [15] to the gamified application.

interest, (iii) individual interest and, (iv) well-developed individual interest. The output is an increased interest, a change in attitude, and improved self-efficacy towards science.

Each of the arrows pointing towards the gamified application illustrates that the user must re-engage with the content of the application, while the arrows pointing towards a phase of interest illustrates what the application must trigger in a user, according to the model, to transition to the next phase [15]. The figure also outlines how the model contributes to seek answers to the research.

3.2 Development steps

In order to develop the application, we first started by finding applications addressing a similar research question as proposed by this thesis. We then looked at design and visual aspects of other gamified applications, identified during the literature review. Looking at how other researchers had tackle the challenge, we grounded the design and what we wanted different components of the application to achieve in the the four phase model of interest development [15]. The development steps for the application, from the literature review through the implementation of the mobile application, is illustrated in Figure 3.2.

To acquire a better understanding of how the application could contribute to the research question and get an overview of the functional requirements, we created a prototype in Figma[1]. Screenshots of various wireframes in the prototype is included in Appendix A. The prototype contributed to define the list of functional requirements and to discover more requirements we could add to the list. The list of functional requirements for the application can be seen in Table B.1. After the list of functional

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

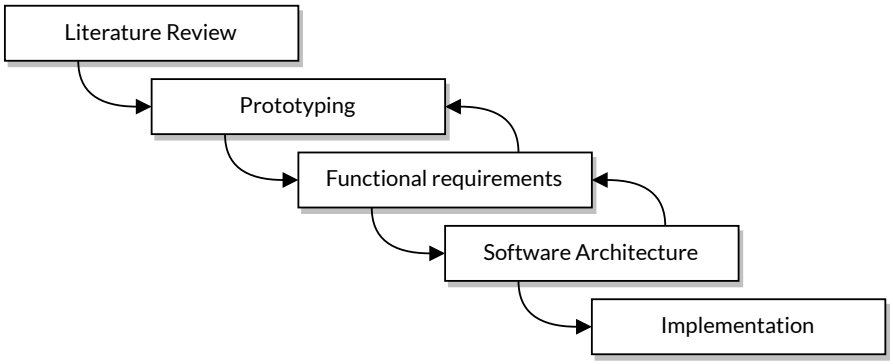


Figure 3.2: Development steps taken from planning to finished application.

requirements were formed, we gave each requirement an ID, description, and a priority. We then sorted the list based on categories the different requirements fit into. For example FR1 is requirements related to the user profile, while FR2 is related to the categories a challenge belongs to.

Having a complete list of requirements allowed us to start defining a software architecture for the application incorporating the requirements. This process was started by constructing architectural views (Appendix B.2.1) of the different components (Figure B.1) and packages (Figure B.2) the system consist of. The architectural views are grounded in Kruchten 4+1 architectural view model [63]. The component and package diagram belongs to the development view *"represented by module and subsystem diagrams that show the system's export and import relationship"*. The component diagram represents the different parts of the system which could be developed independently by different development teams. The package diagram on the other hand, divides the modules into certain areas of responsibility and features the modules will provide. How the system will provide its features and how it will address the system requirements are the responsibility of the logical view (Appendix B.2.3).

The views were illustrated using the Unified Modeling Language (UML). UML is a language used *"to make statements about the system's classes and how they're related"* and *"serve as a design system"* [64]. It is a useful tool to illustrate how an architecture can facilitate and accommodate the system requirements. Different types of diagrams from Kruchen's 4+1 architectural view model [63] combined with UML allows the architecture to be presented in a meaningful way to different stakeholders and address their different interests. The previous steps gave a good overview of how the system should achieve what we wanted to accomplish, and path the way to start the implementation.

Two main concerns arose at the start of the implementation that we had to address; how our system were going to support a control and experimental version (Appendix B.2.5), and what development tools to use. For the first concern we discussed two options. The first option was to create two versions of the system; one version stripped for game elements and another version with game elements. The second option was to

introduce a permission system where the game elements were switched on or off based on the user's granted permission. The first option requires that one of the versions are implemented first, lets say the control version, and then expand the rules and logic into a second separate version which becomes the experimental version. The upside of this approach is that the two versions are independent of one another. Data could be stored in separate databases, distinguishing data from the control and experimental conditions. Downside with this approach is that both versions must be maintained and make the execution of the research design more complex as participants must install and uninstall the two versions during the experiment.

The second option, which we chose, allows for a single implementation, the experimental version, where the user profile has a permission. The permission a user could have are control or experimental. Given the permission of the user, the backend can use the permission to restrict access to endpoints and data returned. The downside of this approach is that more logic is required to make sure correct data is returned and features are restricted as intended. The upsides of this approach are that only a single version must be maintained, allows for automatic switching of permissions during research, and participants install a single version of the application. To summarize, a permission system lessen the complexity of administrating a research, but increases the complexity of the implementation.

3.3 Development tools

The development of the application required the use of several tools to arrive at the final product. Different tools were required for the backend and frontend as each of them have different demands and purposes. In the following subsections we will describe the tools and technologies used for both the backend and frontend of the application.

3.3.1 Backend

The tools used for the backend had to meet the requirement of throughput, scalability, and ease of exchanging data between frontend and backend. To exchange data, we used GraphQL[2]. GraphQL is a query language for application programming interfaces (APIs), which allows clients of an API to specify precisely the data it needs. GraphQL makes the server-side less complex as a single endpoint supports the return of all the data specified by the endpoint or a set of the data. GraphQL also supports clients to subscribe to data updates over the WebSocket protocol. Because GraphQL does not itself have built-in support for subscriptions in production environments, third-party services like Redis[3] is needed to provide this feature. In production, GraphQL uses the cache service of Redis to push data updates to subscribing clients.

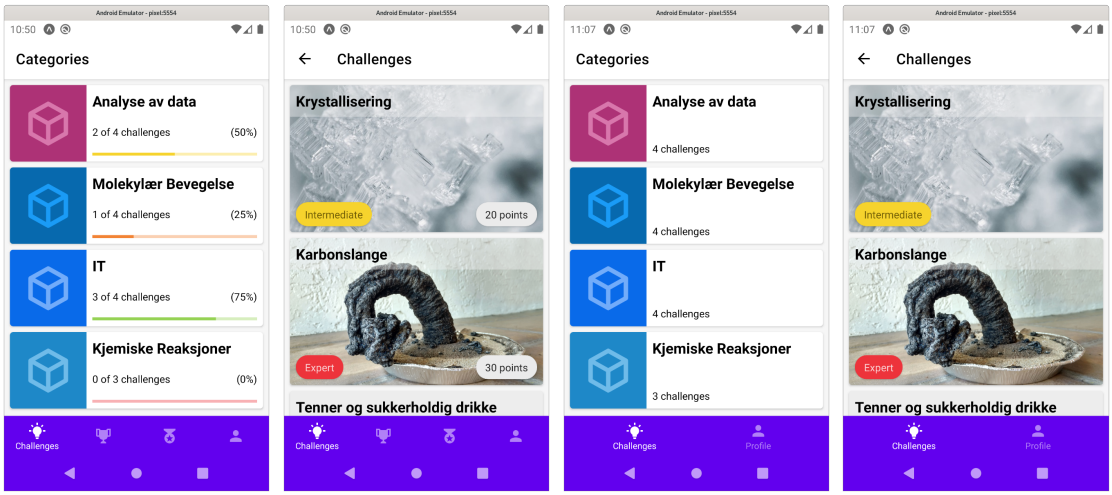
[2]https://graphql.org/
[3]https://redis.io/

The backend application was implemented in JavaScript using Node.js and the Express framework to meet the requirements of scalability and throughput. Furthermore, we used Google Cloud Firestore[4] and Google Cloud Storage[5] to take care of storage of data. Dynamic data for the application was stored in Cloud Firestore, while static data, like images, was stored in Cloud Storage. An advantage of using Cloud Firestore and Cloud Storage is the local emulators available for download. We used the emulators to serve data when running the application in our local development environment. Google App Engine was used to host the application in production mode. It takes care of all server configurations and security settings and saves time during deployment of the application.

3.3.2 Frontend

To make the frontend mobile application available to as many potential participants as possible, we wanted to target both the Android and the Apple iOS mobile platforms. We therefore needed to use tools and technologies that got us up-and-running quickly with a fast time-to-market. As such, the mobile application is implemented in JavaScript using the React Native framework[6]. React Native is an open source user interface (UI) framework that makes it possible to develop cross-platform mobile applications with native capabilities from a single code-base. Compared to developing one application targeting Android and another targeting Apple iOS, the use of a framework like React Native provides a much faster time-to-market. To further speed up development time we decided to make use of tools and services from the Expo[7] ecosystem. The Expo ecosystem provides tools and services enhancing the React Native framework. Most notably, we took advantage of (i) the Expo Go app; for hot reloading during development and testing, and (ii) Expo Application Services (EAS); for building and deploying Android and iOS applications to Google Play and App Store respectively. The Apollo Client[8] library was used to communicate with the backend GraphQL API. Furthermore, we made use of a number of other popular React Native libraries, such as (i) React Navigation[9]; for in-app navigation management and click-stream collection, and (ii) React Native Paper[10]; for a modern cross-platform theme based on Material Design. On the frontend we also added integration with Sentry[11] for application monitoring and error tracking. This made us able to respond to possible software errors after the mobile application was deployed to the respective app stores.

[4]https://cloud.google.com/firestore
[5]https://cloud.google.com/storage
[6]https://reactnative.dev/
[7]https://expo.dev/
[8]https://www.apollographql.com/apollo-client
[9]https://reactnavigation.org/
[10]https://callstack.github.io/react-native-paper/
[11]https://sentry.io/



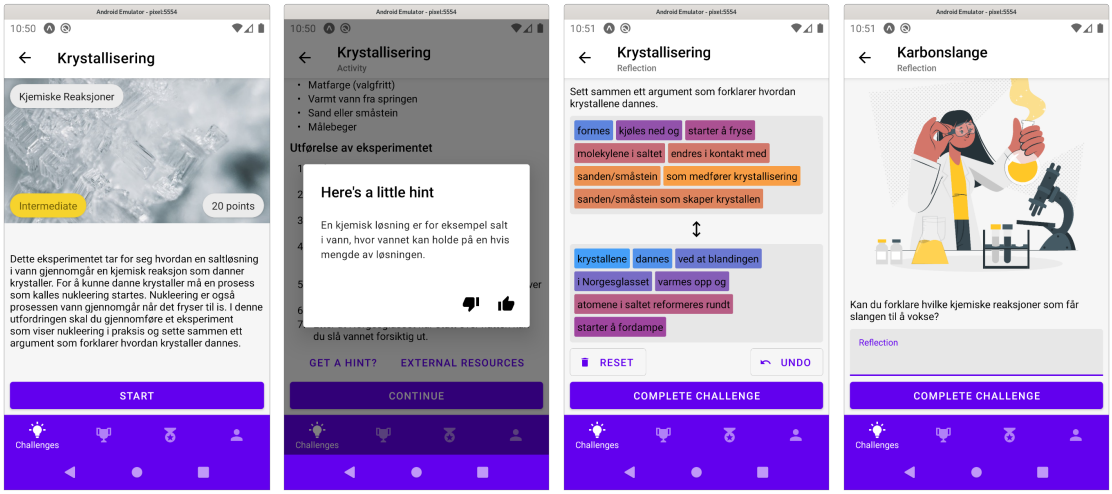
(a) List of categories with game elements enabled. **(b)** List of challenges with game elements enabled. **(c)** List of categories stripped of game elements. **(d)** List of challenges stripped of game elements.

Figure 3.3: A selection of screenshots from the mobile application. The list of categories and challenges in the gamified version of the application are shown in Figures 3.3a and 3.3b, while Figures 3.3c and 3.3d shows the same lists in the non-gamified version of the application. Note that the name of categories and challenges are in Norwegian (the native language of the participants).

3.4 Design decisions

The application includes categories of challenges that cover different STEM-topics and the users can choose the one they prefer. Giving users different categories to explore provides a potential for the application to trigger the situational interest of a wider audience. For each category the number of challenges and the user's progress are shown (Figure 3.3a). As situational interest is triggered suddenly and last for a short period of time [15], topics must be given names that catch the users' attention and trigger their curiosity to further investigate the content. This is why names like *Molekylær Bevegelse* ("Molecular Movements" in English) and *Kjemiske reaksjoner* ("Chemical Reactions" in English) have been chosen. In addition, due to the implication re-engagement over time has on developing interest [15], the number of challenges in the application must be limited. Therefore we included a total number of 15 challenges as this allows the user to re-engage more often with content they find interesting.

To address the different skill levels of users, challenges with varying degree of difficulty are presented when a category is selected (Figure 3.3b). Each challenge has a name, picture for illustration, a difficulty level, and number of points that can be earned by completing the challenge (Figures 3.3b and 3.4a). When the user selects a challenge its description appears together with the choice to start it (Figure 3.4a). When starting a challenge, the user sees the description of what they need for the challenge and a step by step guide on how to proceed with it. The challenges are given from the application's



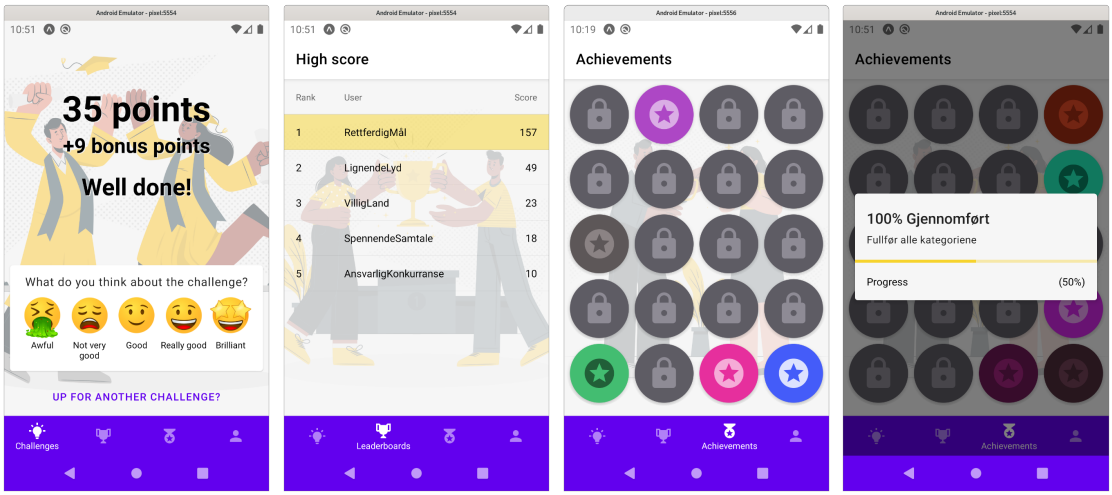
(a) Introducing a challenge. **(b)** A challenge hint. **(c)** Reflecting on a challenge by constructing an argument. **(d)** Reflecting on a challenge with free text.

Figure 3.4: A selection of screenshots from a challenge in the mobile application. A challenge consist of multiple steps. It begins with an introductory description and an option of start it (Figure 3.4a), followed by an activity task (Figure 3.4b), and a reflection task (Figures 3.4c and 3.4d). Note that all textual content of the challenge is in Norwegian (the native language of the participants).

content, but the user should complete them outside the application's environment, giving them a hands on approach with the content. This is related to people's self-efficacy that can be improved by allowing the users to experience challenging content they can master. Mastering content can make the user experience a positive effect towards the content, which is required to develop a maintained situational interest [15]. According to Hidi and Renninger [15] for maintained situational interest to develop into individual interest, external support from the environment is needed. The application facilitates this kind of support by providing hints (Figure 3.4b) and links to external resources. This will help users to better understand the problem presented to them.

After the user has completed the activity task of a challenge, they proceed to the reflection task. The reflection task involves either reflection using free text (Figure 3.4d) or the construction of an argument (Figure 3.4c). The free text reflection requires the user to answer a question related to what they did in the challenge. The argument creation requires the user to select boxes of words or sentences, and drag them over an area to create a valid argument explaining what they learnt from the challenge. The purpose of the reflection tasks are to make the user connect the knowledge to real world problems.

After completing a challenge (Figure 3.5a), the application (i) visualize the number of points earned, (ii) increases the progress for the selected category, and (iii) increases the progress for linked achievements. The points earned are used to rank the user on a high score leader-board (Figure 3.5b). The leader-board shows the user how they compete



(a) Completing a challenge. **(b)** High score leader-board. **(c)** List of achievements. **(d)** Information on an achievement.

Figure 3.5: A selection of screenshots of game elements in the mobile application. When completing a challenge users earn points and are given the possibility to rate the challenge (Figure 3.5a). The points are used to rank users in a high score leader-board based (Figure 3.5b). Completing challenges also enables users to unlock achievements (Figures 3.5c and 3.5d).

against others participating in the research project. The high score leader-board updates for all users every time a user completes a challenge, providing visual feedback to other users about the new standings. The leader-board is a part of the game elements in the application because there are indications that it triggers participants interest in personal comparison, making them engaged [65]. The comparison of placement on the leader-board can increase use of the application due to curiosity, as another finding of the study indicates. Leader-boards can reinforce positive affect in the user if it provides a feedback of success [66], and can be further enhanced by leader-boards' ability to increase the learning performance of the user [67].

The progress is displayed on each category to make the user aware of how much they have achieved so far. Each achievement displays the progress to inform the user of what is left to do. Achievements in the application have a progressive structure where the user can complete individual challenges, all challenges with a given difficulty level or within a category to earn achievements. This structure is meant to provide the user with an incentive to gradually complete all challenges and be rewarded for their effort. It is also used to trigger intrinsic motivation and use that as a driver for further development of interest [19]. The achievements are used to motivate and encouraged re-engagement with the content (Figures 3.5c and 3.5d). Achievements include both repetitive and topic badges. Most emphasis is placed on repetitive badges as there are indications that they appeal to a broader audience [18].

4 Methodology

This chapter describe the research methods used for the empirical study in this thesis. The chapter is divided into five sections. It starts by describing the participants and the process they went through before, during, and after the experiment. A description of the data collection follows, including how the data was collected and what measures it contains. Finally a description of the research design is provided. Our research project have been granted an ethical approval by the Norwegian centre for research data (NSD).

4.1 Participants

In order to recruit participants for our research project, we made in total three recruitment attempts. The first attempt was made in August 2021, as part of the initial phases of the preparatory project for the thesis. Through connections to a science teacher at Melhus videregående skole, we established an informal agreement on students who could participate in our research. In early February 2022, one and a half months before the planned start of the experiment, the formalization of the agreement was rejected due to high sickness absence related to COVID-19, among both students and teachers. Our second attempt started immediately after the rejection. We reached out to multiple schools in the Trondheim area through email and phone, but the response on these requests was very low and served unfruitful. Realizing that it was difficult to achieve the goal of recruitment within the planned start-up for the experiment, we made the decision to postpone the start-up until after Easter in mid-April. In the continuation of recruiting participants, we once again used our connections to previous teachers and expanded recruitment to other parts of Norway. In our third attempt we were finally able to recruit enough students from Amalie Skram videregående skole in Bergen.

The process of recruiting participants involved (i) giving a presentation of our research project to potential participants in school, (ii) handing out information letters and forms of consent for the research project (Appendix C), and (iii) collecting consent from those who wanted to participate. For students aged 17 and younger, we also needed to collect the consent of their parents or legal guardians. After presenting our project to 92 students aged 15 to 19 years, we ended up collecting consent from a total number of 46 students. All of which were graduate students aged 18 to 19 years.

4.2 Procedure

At the start of the experiment, each participant was provided with a unique username. The username was used to both grant access to the application and link data from questionnaires to each respective user. All usernames were pre-registered in the application and assigned either a control or experimental condition. An equal number of usernames from both conditions, matching the total number of participants, were mixed in a single envelope. Each user drew a username from this envelope before they proceeded with answering the first questionnaire. They then were provided with links to download and install the application, from either Google Play or App Store, and used their username to activate their accounts. Only 12 participants out of 46 showed up the first day, and a second onboarding was needed to include remaining participants. The same procedure was repeated for the second onboarding and resulted in 9 more participants joining the experiment. In the end, we ended up with a total of 21 participants joining the experiment.

After all participants had answered the first questionnaire, they used the application for one and a half weeks. At the end of the first period the users answered a second questionnaire. Out of 21 answering the first questionnaire, only 11 answered the second one. Due to students missing out on the second information session, some of the questionnaires were not answered in time, according to the schedule of the experiment. For the second period, the experiment conditions were swapped. Participants in the control condition were now assigned to the experimental condition and vice versa. The participants used the application for another one and a half weeks, before answering a last questionnaire. The same 11 participants answered the last questionnaire. Including the time between the first and the second onboarding, the experiment lasted for a total of four weeks, with a total of three questionnaires being filled out by each participant.

4.3 Data collection

For this study quantitative data was collected using log and usage data from the application, as well as from questionnaires. Data from the questionnaires was collected both pre and post experiment. In the pre-questionnaire, data about participants' science capital, interest for science, attitude towards science, and self-efficacy in science, was collected. For the post-questionnaire, data about participants' intrinsic motivation for the different game elements was collected in addition to their interest for, attitude towards, and self-efficacy in science post experiment. A description of variables computed from the collected data is provided in Table 4.1.

Participants' science capital were assessed using 5-point Likert-scale items derived from previous studies by Moote *et al.* [47] and DeWitt *et al.* [68]. Their science capital index was calculated by taking the sum of the weighted answers divided by the number of items, and transforming the scores along a scale from 0 to 100, as recommended by

Table 4.1: Description of variables in the dataset.

Variable	P[a]	C[b]	E[c]	Datatype	Value	Description
Participant ID	×	×	×	String		The participant's unique ID
Gender	×			String	$\{M, F\}$	The participant's gender
Science capital index	×			Numerical	$[0, 100]$	The participant's science capital index
Attitude	×	×	×	Numerical	$[1, 5]$	The participant's attitude score
Interest	×	×	×	Numerical	$[1, 5]$	The participant's interest score
Self-efficacy	×	×	×	Numerical	$[1, 5]$	The participant's self-efficacy score
IMI App		×	×	Numerical	$[1, 5]$	IMI score for the application
IMI Achievements			×	Numerical	$[1, 5]$	IMI score for the game element *Achievements*
IMI Leader-board			×	Numerical	$[1, 5]$	IMI score for the game element *Leader-board*
IMI Progress			×	Numerical	$[1, 5]$	IMI score for the game element *Progress*
IMI Points			×	Numerical	$[1, 5]$	IMI score for the game element *Points*
Views Achievements			×	Numerical	$[0, \infty)$	Number of times the participant has viewed achievements in the app
Views Leader-board			×	Numerical	$[0, \infty)$	Number of times the participant has viewed the leader-board in the app
Points			×	Numerical	$[0, 426]$	Number of points collected in the app
Progress Categories			×	Numerical	$[0, 100]$	The participant's progress in categories
Progress Achievements			×	Numerical	$[0, 100]$	The participant's progress in achievements
Achievements received			×	Numerical	$[0, 20]$	Number of achievements received in the app

[a] P = Pre-condition (measured before the treatment)
[b] C = Control condition (measured after the treatment)
[c] E = Experimental condition (measured after the treatment)

Moote *et al.* [47]. Weighting of response choices for items comprising science capital is identical to Moote *et al.* [47] and can be found in Table G.1.

Data related to the participants' attitude was captured using the *attitudes to science measures* questionnaire [69]. The questionnaire uses 5-point Likert-scale items and captures students' attitudes towards science learning activities, value of science in social contexts, their beliefs in own ability to do science, and their future belief of engaging more with science. According to Kind *et al.* [69] all constructs of the questionnaire have a high internal reliability, with a Cronbach's Alpha value greater than 0.7. To assess self-efficacy we used the knowledge dimension from the *Academic interest scale for adolescents* questionnaire [70] and the self-efficacy scale used by Chen *et al.* [21]. Both of the the questionnaires use 5-point Likert-scale items and was adjusted to measure self-efficacy for science. The *Academic interest scale for adolescents* questionnaire is used because it address peoples confidence in science. It has a Cronbach's Alpha value of 0.98, with the knowledge dimension having a value of 0.88 for internal validity. It is a generic multidimensional instrument measuring academic interest using the four-phase model of interest development [15] as its foundation. According to Chen *et al.* [21] the self-efficacy scale used have Cronbach's Alpha values of 0.88 and 0.93 for pre and post questionnaires, respectively. The scale measure participants self-efficacy related to science inquiries.

To measure the interest in game elements we used an intrinsic motivation inventory (IMI) scale questionnaire [71]. According to Ostrow and Heffernan [71], the IMI scale

can be configured to suit different research needs. For this research we used the interest and enjoyment questions from the scale. The Cronbach's Alpha value for the interest and enjoyment section of the questionnaire is 0.91. The IMI scale is a multidimensional scale measuring participants experience with task participation. The scale, as used by Ostrow and Heffernan [71], is a 7-point Likert-scale. We used the scale with a 5-point Likert-scale instead to avoid confusion for participants and to remain consistent between all questionnaires used. All questionnaires used for this study were translated to Norwegian to enhance the comprehension of the Norwegian participants of this study. The aim was to investigate potential differences in our participants interest and attitude pre- and post-experiment after being exposed to game elements.

We also collected click stream data from participants' use of the application. This data was used to analyze and understand how the participants used and navigated in the application. The click stream data contains information about what screens they have interacted with, when they have logged in and out of the application, when they started and finished a challenge, and when they used hints and external resources recommended by the application. The aim of collecting click stream data is to support the data from the questionnaires to further investigate if game elements contributes to a potential difference in interest and attitude [21].

4.4 Research design

A randomized experimental mixed research design was applied to the empirical study in this thesis. The design combines between-subjects and within-subjects comparison of the variable of interest, as illustrated in Figure 4.1. This combination involves conducting two between-subjects sub-experiments, where a within-subjects strategy is applied between the end of the first and start of the second. At the start of the experiment, the sample was split in two groups by randomly assigning each participant either a control or experimental condition. Halfway through the experiment, at the end of the first sub-experiment, the conditions for the two groups were swapped. Participants answered questionnaires before the experiment and after each sub-experiment.

4.5 Data analysis

The statistical analysis was performed in R (4.2.0) using R Studio (2022.02.2, build 458) on both Linux and Windows. We tested assumptions such as normal distribution, and ran t-tests for hypothesis testing. For the t-test we used the difference in interest and difference in attitude as our dependent variables. The independent variables *Views Leader-board*, *Views Achievements*, *Progress Categories*, *Progress Achievements*, *Points*, *IMI Progress*, *IMI Points*, *IMI Leader-board*, and *IMI Achievements*, were tested against each dependent variable.

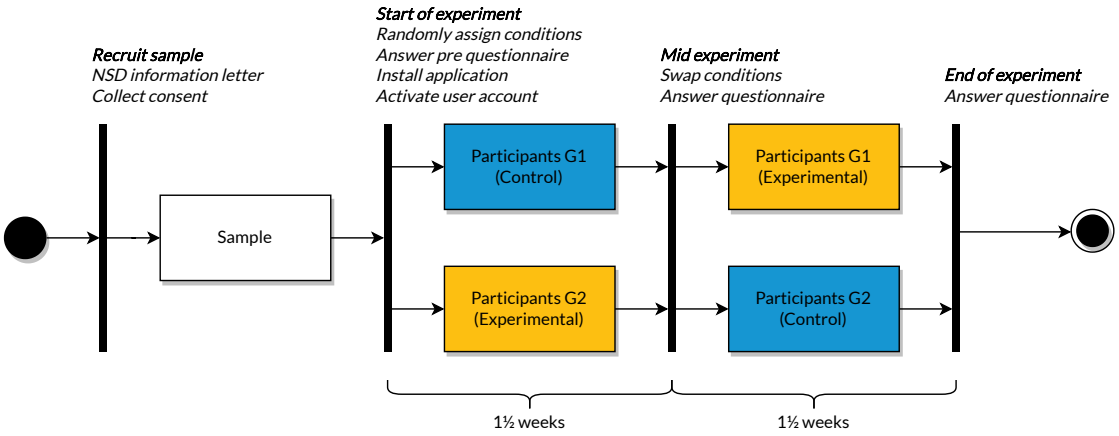


Figure 4.1: Illustration of the research design and procedure of the research project.

5 Results

This chapter presents the result and findings from the empirical study conducted as part of the thesis. The chapter is divided into four sections. It starts by providing descriptive statistics of the collected data, before the results from running statistical tests on the data are presented. Test results are presented chronologically according to the hypotheses and sub-hypotheses listed in Section 1.2, and are grouped by themes relevant to the research question.

5.1 Descriptive statistics

The participants expressed a moderate interest ($M = 2.64$) and moderate positive attitude ($M = 3.26$) towards science. Moderate level of interest indicates that they have a fluctuating intrinsic motivation to do science. A moderate positive attitude indicates that they react neither positively or negatively when engaging with science related activities. Furthermore, the participants report a moderate self-efficacy ($M = 3.3$) for science. This indicates that they have a moderate belief in them self to produce their desired attainment in science. Descriptive statistics about the participants' development in interest and attitude, and game element metrics are summarized in Table 5.1.

Table 5.1: Descriptive statistics of the study.

Condition	Variable	Mean	Median	SD	Min	Max
Pre	Science capital index	54.59	55.36	11.89	32.14	76.79
Pre	Attitude	3.26	3.24	0.4	2.41	3.96
Pre	Interest	2.67	2.5	0.98	1	4.33
Pre	Self-efficacy	3.3	3.38	0.64	2.12	4.5
Control	Attitude	4.16	4.17	0.4	3.17	5
Control	Interest	2.59	2.5	0.84	1.5	5
Control	Self-efficacy	3.45	3.5	0.37	2.12	4.12
Control	IMI App	2.98	3	0.32	2.2	3.8
Control	Difference in Interest	−0.09	0	0.86	−1.83	1.5
Control	Difference in Attitude	0.89	0.99	0.41	0.12	1.75
Control	Difference in Self-efficacy	0.15	0.12	0.61	−1	1.38
Experimental	Attitude	4.02	4	0.44	3	5
Experimental	Interest	2.68	2.67	0.82	1.17	5
Experimental	Self-efficacy	3.37	3.5	0.57	1.88	4.5
Experimental	IMI App	3.04	3	0.39	2.2	4
Experimental	IMI Achievements	3.04	3	0.25	2.4	3.6

Continues on the next page...

Table 5.1: Descriptive statistics of the study (continued).

Condition	Variable	Mean	Median	SD	Min	Max
Experimental	IMI Leader-board	3.15	3	0.69	2	5
Experimental	IMI Progress	3.29	3.2	0.43	2.4	4.6
Experimental	IMI Points	3.55	3.4	0.54	3	5
Experimental	Views Achievements	1.43	0	2.2	0	8
Experimental	Views Leader-board	2.14	0	3.79	0	14
Experimental	Points	9.95	0	27.14	0	111
Experimental	Progress Categories	2.48	0	6.27	0	25
Experimental	Progress Achievements	2.31	0	6.21	0	25.77
Experimental	Achievements received	0.24	0.00	0.89	0.00	4.00
Experimental	Difference in Interest	0.01	0	0.81	−1.67	1.67
Experimental	Difference in Attitude	0.76	0.85	0.36	0.15	1.26
Experimental	Difference in Self-efficacy	0.07	0	0.65	−1	1.38

5.2 Interest

To answer our main hypothesis related to interest (hypothesis H1), we used independent samples t-tests to test sub-hypotheses H1a to H1d. For all tests the difference in attitude between the experimental and pre condition was used as the dependent variable. Full test results for these t-tests can be seen in Table 5.3.

Sub-hypothesis H1a was tested with two t-tests using *View Achievements* and *IMI Achievements* as independent variables, respectively. The first test showed that participants viewing achievements in the app, ($M = 1.43, SD = 2.2$), had a significant increase in their interest for science, $t(25) = -2.77, p = .01027$. In the second test, we also observed a significant increase in interest, $t(24) = -16.44, p < .001$, for the participants who reported an intrinsic motivation for achievements ($M = 3.05, SD = .3$) after using the gamified application.

To test sub-hypothesis H1b we ran two t-tests using *View Leader-board* and *IMI Leader-*

Table 5.3: Independent samples t-test results for game elements' effect on interest (hypothesis H1).

				Difference		95% Conf. Interval of the Difference	
Variable	t	df	p	Mean	Std. Error	Lower	Upper
Views Leader-board	−2.5278	21.8145	0.0192376^{*}	2.1349	0.8446	−3.8874	−0.3825
Views Achievements	−2.7738	25.2691	0.0102664^{*}	1.4206	0.5122	−2.4749	−0.3664
Progress Categories	−1.7917	20.6622	0.0878422	2.4722	1.3798	−5.3446	0.4001
Progress Achievements	−1.6858	20.6763	0.1068607	2.3022	1.3656	−5.1448	0.5404
Points	−1.6840	20.0539	0.1076877	8.0873	4.8025	−18.1034	1.9288
IMI Progress	−16.4123	30.5754	$1.041 \times 10^{-16***}$	3.2778	0.1997	−3.6853	−2.8702
IMI Points	−16.7269	34.9187	$3.022 \times 10^{-18***}$	3.5444	0.2119	−3.9747	−3.1142
IMI Leader-board	−13.5498	39.0988	$2.356 \times 10^{-16***}$	3.1444	0.2321	−3.6138	−2.6751
IMI Achievements	−16.4357	23.8019	$1.716 \times 10^{-14***}$	3.0302	0.1844	−3.4108	−2.6495

Significance codes: $(p < .001)^{***}$ $(p < .01)^{**}$ $(p < .05)^{*}$

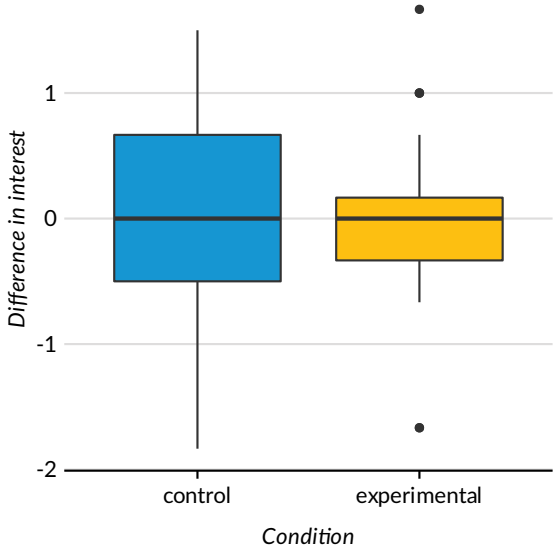


Figure 5.1: Boxplot for the difference in interest between the control and experimental conditions.

board as independent variables. The results from the first test showed that participants exposed to the leader-board in the gamified application ($M = 2.14, SD = 3.79$) had a significant increase in their interest for science, $t(22) = -2.52, p = .0192$. Also for the second test, participants that reported an intrinsic motivation for the leader-board ($M = 3.37, SD = .87$) had an significant increase in their interest for science, $t(39) = -13.55, p < .001$.

We continued to test sub-hypothesis H1c by running three t-tests with *Progress Achievements*, *Progress Categories*, and *IMI Progress* as independent variables, respectively. For the two first tests, we found no significant effect on the progress participants had made on either achievements, $t(21) = -1.69, p = .11$, or categories, $t(21) = -1.79, p = .088$, while using the gamified application, compared to their change in attitude. However, participants reporting an intrinsic motivation for the game element progress ($M = 3.57, SD = .54$), had a significant increase in their interest for science, $t(31) = -16.41, p < .001$.

The final sub-hypothesis H1d related to interest was tested by running two t-tests using *Points* and *IMI Points* as the independent variable. We found no significant effect on the number of points participants collected in the application, $t(20) = -1.68, p = .108$, compared to their change in interest. However, a significant increase in interest, $t(35) = -16.73, p < .001$, was observed for those who reported an intrinsic motivation for points ($M = 3.83, SD = .73$).

Even though tests showed significant results for participants exposed to the game elements achievement and leader-board, a comparison to the control group indicates otherwise (Figure 5.1). Running a t-test with the difference in interest in the control and experimental conditions shows no significant difference between the two

Table 5.4: Independent samples t-test results for game elements' effect on attitude (hypothesis H2).

				Difference		95% Conf. Interval of the Difference	
Variable	t	df	p	Mean	Std. Error	Lower	Upper
Views Leader-board	-1.6670	20.3530	0.1108346	1.3830	0.8297	-3.1117	0.3457
Views Achievements	-1.3728	21.0407	0.1842841	0.6687	0.4871	-1.6817	0.3442
Progress Categories	-1.2550	20.1286	0.2238438	1.7203	1.3707	-4.5785	1.1378
Progress Achievements	-1.1429	20.1314	0.2664839	1.5503	1.3564	-4.3785	1.2780
Points	-1.5520	20.0069	0.1363494	9.1925	5.9232	-21.5479	3.1628
IMI Progress	-20.6979	38.5880	$1.702 \times 10^{-22***}$	2.5259	0.1220	-2.7728	-2.2790
IMI Points	-19.7916	34.6004	$1.898 \times 10^{-20***}$	2.7925	0.1411	-3.0791	-2.5060
IMI Leader-board	-14.0833	29.8612	$1.005 \times 10^{-14***}$	2.3925	0.1699	-2.7396	-2.0455
IMI Achievements	-24.0190	35.8845	$1.051 \times 10^{-23***}$	2.2783	0.0949	-2.4707	-2.0859

Significance codes: $(p < .001)^{***}$ $(p < .01)^{**}$ $(p < .05)^{*}$

conditions, $t(40) = -0.37, p = .7134$. Participants exposed to the control condition ($M = -0.09, SD = .86$) experienced a small decrease in interest, while those exposed to the experimental condition ($M = .01, SD = .81$) experienced a very small increase.

5.3 Attitude

To answer our main hypothesis related to attitude (hypothesis H2), we used independent samples t-tests to test sub-hypotheses H2a to H2d. For all tests the difference in attitude between the experimental and pre condition was used as the dependent variable. Full test results for these t-tests can be seen in Table 5.4.

We used two independent samples t-tests to test sub-hypothesis H2a. For the first test, the *Views Achievements* variable was tested against the difference in attitude for the experimental condition. There was no significant effect on the number of times participant's viewed achievements in the application, $t(21) = -1.37, p = .184$, compared to their change in attitude. For the second test, we used the *IMI Achievements* as the independent variable. Participants that reported an intrinsic motivation for achievements ($M = 3.04, SD = .25$) had an significant increase in their positive attitude towards science, $t(36) = -24.01, p < .001$.

For sub-hypothesis H2b, we used *Views Leader-board* and *IMI Leader-board* as independent variables in two independent samples t-tests. For the first test, we found no significant effect on the number of times participant's viewed the leader-board in the application, $t(20) = -1.67, p = .11$, compared to their change in attitude. In the second test, we found that participants reporting an intrinsic motivation for leader-boards ($M = 3.15, SD = .69$) had an significant increase in positive attitude towards science, $t(30) = -14.08, p < .001$.

To test sub-hypothesis H2c, we ran three independent samples t-tests using *Progress Achievements*, *Progress Categories*, and *IMI Progress* as independent variables, respectively. For the two first tests, we found no significant effect on the progress participants had

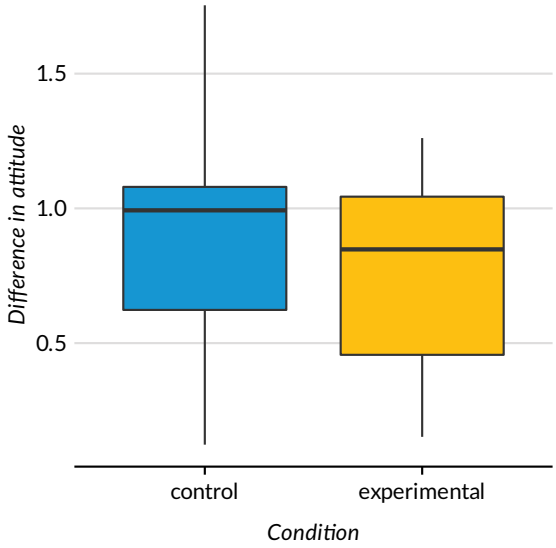


Figure 5.2: Boxplot for the difference in attitude between the control and experimental conditions.

made in the application for either achievements, $t(20) = -1.14, p = .27$, or categories, $t(20) = -1.26, p = .22$, compared to their change in attitude. For the third test, we found that participants reporting an intrinsic motivation for progress ($M = 3.29, SD = .43$) had an significant increase in positive attitude towards science, $t(39) = -20.7, p < .001$.

Lastly, we ran another two independent samples t-tests to test sub-hypothesis H2d. For the first test the *Points* variable was tested against the difference in attitude for the experimental condition. We found no significant effect on the number of points participants collected in the application, $t(20) = -1.55, p = .14$, compared to their change in attitude. For the second test the *IMI Points* variable was tested against the difference in attitude. Here we found that participants reporting an intrinsic motivation for points ($M = 3.55, SD = .54$), had an significant increase in positive attitude towards science, $t(35) = -19.8, p < .001$.

We used an independent samples t-test with the difference in attitude as the independent variable to validate the results against the control group (Figure 5.2). The result shows no significant difference between the control and experimental conditions, $t(39) = 1.14, p = .26$. Both participants exposed to the control condition ($M = .89, SD = .41$) and the experimental condition ($M = .76, SD = .15$) experienced a small increase in positive attitude towards science.

5.4 Demographics

As illustrated in Figure 5.3, nine males and twelve females participated in the study. To check for gender bias within our sample, we ran independent samples t-tests or bootstrap t-tests. No significant results were found, except when testing difference in interest for

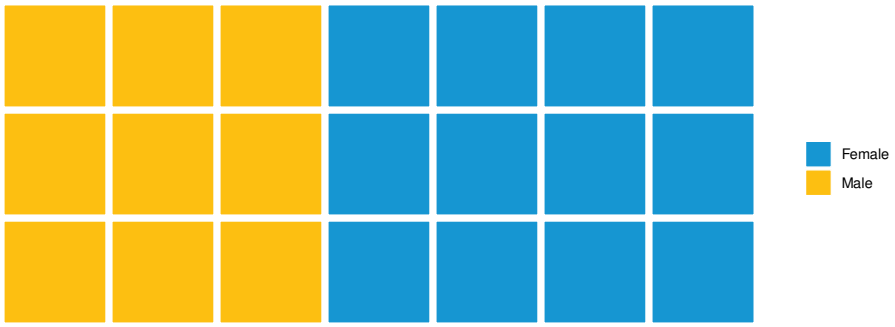


Figure 5.3: Waffle chart showing the gender distribution among students participating in the study. In the sample of 21 participants, there were nine (9) males (42.9%) and twelve (12) females (57.1%).

Table 5.5: Independent samples t-test results for gender.

	With bootstrap	t-test for Equality of Means						
					Difference		95% Conf. Interval of the Difference	
Variable	p	t	df	p	Mean	Std. Error	Lower	Upper
Diff. Interest (control)		2.1639	19	0.0434^{*}	−0.7546	0.3487	0.0247	1.4845
Diff. Interest (experimental)	0.0078^{**}	2.6357	17.327	0.0172^{*}	−0.8241	0.3127	0.1654	1.4828
Diff. Attitude (control)		0.0327	19	0.9742	−0.006	0.1845	−0.3801	0.3922
Diff. Attitude (experimental)		1.0135	19	0.3236	−0.1588	0.1567	−0.1692	0.4868
Diff. Self-efficacy (control)		0.3291	19	0.7457	−0.0903	0.2743	−0.4839	0.6644
Diff. Self-efficacy (experimental)		1.025	19	0.3182	−0.2951	0.2879	−0.3075	0.8978
Views Achievements	0.2222	1.4306	18.3814	0.1693	−1.3333	0.932	−0.6219	3.2886
Views Leader-board	0.4636	0.9717	17.9002	0.3441	−1.6111	1.658	−1.8736	5.0958
IMI App (control)	0.0022^{**}	−2.7362	15.3409	0.0151^{*}	0.3444	0.1259	−0.6122	−0.0766
IMI App (experimental)	0.4332	−0.7221	15.8129	0.4808	0.1278	0.1769	−0.5033	0.2477
IMI Achievements	0.9303	−0.091	11.8757	0.9290	0.0111	0.1221	−0.2774	0.2552
IMI Leader-board	0.6751	−0.3844	16.0828	0.7057	0.1222	0.318	−0.796	0.5515
IMI Progress	0.8147	0.3421	11.5628	0.7384	−0.0722	0.2111	−0.3897	0.5342
IMI Points	0.9473	−0.0224	16.5094	0.9824	0.0056	0.2475	−0.5289	0.5178

Significance codes: $(p < .001)^{***}$ $(p < .01)^{**}$ $(p < .05)^{*}$

experimental condition and their intrinsic motivation for the application related to the control condition. The results from testing difference in interest shows a significant difference between genders in development of interest for participants exposed to the experimental condition, $t(17) = 2.63, p = .0171$ ($p = .0058$ with bootstrap). When we tested for their intrinsic motivation for the application, we found a significant difference between genders for the control condition, $t(15) = -2.73, p = .015$ ($p = .0028$ with bootstrap). The results for all the variables tested against gender can be found in Table 5.5.

6 Discussion

In this chapter, the results and findings from the empirical study are discussed. The chapter is divided into four sections. First an answer to the research question is provided, followed by a more nuanced discussion, where results and findings for specific game elements are mapped to the literature. The chapter is concluded with a critique of the study, where limitations and shortcomings of the study are addressed.

6.1 Game elements' effect on interest and attitude

In this thesis we investigate the effect game elements have on interest for and attitude towards science. In this section we present an interpretation of the results from our data analysis and answer our hypotheses and research question. The research question for the thesis (introduced in Section 1.2) is as follows:

> *How does the use of game elements in informal science activities affect young adults' interest in and attitude towards science, in the context of a mobile application?*

Our analysis of the data suggests that results are not consistent with our hypotheses answering our research question. According to our findings the game elements as a whole did not affect interest and attitude. The individual game elements achievements and leader-board did, however indicate an effect. Participants' intrinsic motivation for the game elements had the most significant effect on their interest and attitude. Even though the reported intrinsic motivation seemed to have an effect, a validation against the control condition rejected this finding as there were no significant difference between conditions. In the following sections we will discuss findings related to the specific game elements addressed through our hypotheses.

6.1.1 Achievements

Sub-hypotheses H1a and H2a addresses the effect achievements have on interest for and attitude towards science, respectively. They take into account the number of times participants have viewed achievements and their intrinsic motivation for achievements after being exposed to them. Sub-hypothesis H1a was confirmed because the dependent variable, difference in interest, tested against both viewing achievements and intrinsic motivation for achievements found significant results. Sub-hypothesis H2a was rejected because the dependent variable, difference in attitude, tested against viewing achievements found no significant results, even though the test against intrinsic motivation for

achievements found significant results. The results states that viewing achievements and having an intrinsic motivation for achievements after using the application out of school do have an effect on the participants interest, but no effect on attitude. A possible explanation for the result related to interest is that achievement is motivational in educational contexts and impact re-engagement positively [19]. Re-engagement is an important factor when it comes to development of interest [15]. When it comes to achievement and re-engagement, our findings shows that the majority of the participants views achievements a few times and a couple views several times, which is in line with the findings of Denny [19].

6.1.2 Leader-board

Sub-hypotheses H1b and H2b addresses the effect the leader-board have on participants' interest for and attitude towards science, respectively. Our analysis found that participants' intrinsic motivation for the leader-board has a significant effect on both their interest for and attitude towards science. Furthermore, we found that the number of times participants viewed the leader-board had a significant effect on their interest for science, confirming sub-hypothesis H1b. However, for participants' attitude towards science we found no significant effect and, therefore, sub-hypothesis H2b must be rejected.

With regards to participants' interest for science, our results are consistent with findings from Bowey *et al.* [66]. They found the that use of ranking, scores, and feedback in leader-board's resulted in affect changes in their participants. As stated by Hidi and Renninger [15], a long lasting positive affect is essential in the development of interest. It is worth mentioning that while Bowey *et al.* tested a leader-board in a game context, the observed affect changes was independent from the game performance, and should thus be transferable to a non-game context.

6.1.3 Progress

Sub-hypotheses H1c and H2c addresses the effect progress have on interest for and attitude towards science, respectively. Both hypotheses were rejected because no significant results were found when testing participants' progress in categories and achievements against their difference in interest and attitude. However, a significant result was found when testing their difference in interest and attitude against intrinsic motivation for the game element progress. The results state that interacting with content that incorporate progress have no effect on students interest in and attitude towards science. This could be because the element was not properly isolated from other elements and content in the application. In our application, progress was implemented as a part of both categories and achievements. This could make the user pay less attention to their progress, and making it harder to measure properly. Therefore, the metrics collected to analyze the game element progress might play a role in why the results turned out not significant.

6.1.4 Points

Results related to the game element points, addressed by sub-hypotheses H1d and H2d, shows that the hypotheses were rejected. No significant results were found when testing the two dependent variables, difference in interest and difference in attitude, against points collected, but found significant results for intrinsic motivation for the game element points. The results states that even though total points collected by a user did not effect interest in and attitude towards science, their intrinsic motivation for points do have such an effect. To the best of our knowledge there is a shortcoming in the literature focusing on the effect of points on interest and attitude, and therefore we cannot compare this result to other results from the literature. That more studies on the effect of individual game elements are needed, are pointed out in the literature [10, 25, 67].

However, one potential explanation is highlighted by a study that investigate the effect of points on a loyalty program [72]. Their findings support that extrinsic rewards can negatively influence intrinsic motivation, and that it weakened individuals' intrinsic motivation to engage with loyalty programs. This could shed some light upon why collecting points does not affect interest or attitude. Due to individuals becomes less motivated to engage by extrinsic rewards, such as points, makes the basis of developing interest to fade because engagement with content is an important factor in development of interest [15].

6.1.5 Intrinsic motivation for game elements

A very interesting observation from the analysis is the significant results intrinsic motivation for individual game elements had on interest in and attitude towards science. Our interpretation of these results are as follows: the intrinsic motivation for game elements affect both interest in and attitude towards science because the game elements are tightly coupled with the content of the application. This tightly coupling causes an intrinsic motivation for the individual game elements to affect their interest in science. Since interest is correlated with attitude and, therefore, the intrinsic motivation for the individual game elements also affects the participants attitude towards science. There could be three different reasons for this.

The first reason, as shown by Smith [25], is that exposure to gamified applications do have an effect on students' attitudes. The effect on attitude is a result of increased cognitive competence. This in turn increases interest and lower the perceived difficulty, which is related to an increase in self-efficacy [24]. The correlation between interest and attitude could explain why there are significant results across all of these variables. Our results are not one-to-one comparable with the study of Smith [25]. Our study have addressed and conducted research on informal learning out of school, while their study addressed formal learning in school. In our gamified application we presented a variety of different STEM-topics, compared to their gamified application which presented tasks

related to statistics.

The second reason which could moderate the explanation and importance of the result is how our study collected the data related to the intrinsic motivation for the different game elements. In our and comparable studies, intrinsic motivation for game elements were collected post experiment [19, 67]. A difference between our study and the ones compared to, is that they asked for the participants previous experience with or interest in game elements. By not collecting students' intrinsic motivation for the individual game elements prior to the experiment, we have no opportunity to check whether there were an effect between pre and post intrinsic motivation for game elements. The data could have confirmed or denied that the exposure for our application were the cause of a change in intrinsic motivation for the individual game elements and further backed our result. The lack of such data could be one of several reasons why our results show that there are no significant effect on interest in and attitude towards science between the control and experimental conditions, but a significant effect is observed for the intrinsic motivation variables. A test between pre and post intrinsic motivation for game elements potentially could have shed light on this finding.

The third reason for the observation could be that schools in Norway do not use many digital tools for education which incorporate game elements. Therefore, students have no or little initial impression of game elements used within a school context. Based on this knowledge about Norwegian schools and their students, the effect could be due to a novelty effect of introducing game elements into a school context.

6.2 Gender bias

The first significant result for gender bias, looking at the difference in interest for the control condition, states that gender plays a role when it comes to explaining the difference in interest for the control version of the application between genders. As our result shows a significant effect, but yet small, it could either be an indication that it is the case or it could be due to our small sample size not providing enough power to the statistical test making the result less reliable. The second significant result has the same explanation as the first result, but relates to the gamified version of the application. The third significant result, states that there are a difference between genders for their intrinsic motivation in the control condition. With the current data at hand and lack of qualitative data, explaining these observations becomes challenging. As these findings are also out of scope of our research question, they must addressed in a future study.

6.3 Implications for research and practice

Our findings gives an indication that exposing students for achievements and leaderboard, while doing science activities out of school, can enhance their interest in science. This indication can have implications for research by guiding other practitioners in

what game elements to include when further studies of interest in and attitude towards science are conducted. It can also have implications in a school context, where schools can use these game elements when imposing science activities for students out of school. This can be beneficial in reversing the observed decline in students' interest in science and technology [14], and reduce the perceived difficulty of scientific activities [11].

Another implication this study have on research is the contribution of a mobile application that other researchers can use. The application developed for this thesis is made available open-source, and can be used and modified for future studies on gamification. Using the application as a foundation for future research can save time on development and enable more longitudinal studies on game elements.

6.4 Limitations

We acknowledge that there are several limitations and aspects to address which could improved the quality of this study. First of all, it is important to highlight the small sample size. Out of a sample size of 21, all participants answered the pre questionnaire, but only 11 used the application and completed the post questionnaires. Therefore, it is important to state that the results of this study should be interpreted with great caution. According to Gravetter and Wallnau [73, pp. 180–183] a sample size of 30 participants is recommended. This is to ensure good enough statistical power to the tests to make the results reliable. Therefore, since our sample size is 21, the results of this study are less reliable.

Second, as the experiment was conducted out in the wild and not in a laboratory, we as a researchers are in no control of whether the participants show up, or actually follow and do the instructions we provide. This was the case for the procedure of the research for this experiment. Half of the participants were onboarded in a second attempt after not showing up, and participants delivered questionnaires overdue of the deadline. This is a limitation as it potentially could make a differences in the data collected. For example, some participants had more time to use the application and, therefore, potentially skewed the data in favor of either the control or the experimental condition.

Third, we recognize a limitation in how we collected the data and what data was collected. This is mainly related to three things: (i) we should have collected data for intrinsic motivation for individual game elements both pre and post experiment, (ii) the game elements progress and points could have been better isolated to improve metrics and data collection, and (iii) improving how users' was notified when achievements were awarded could diversified the degree of interest in achievements among the users. The first point could have improved the internal validity of the results of this study by verifying the effect of the intrinsic motivation for the individual game elements. The second point could have improved the quality of the data collected for points and progress, which could improved the result. The third point could have made

achievements more visible to the user and allowed the application to log more data about intrinsic motivation towards achievements.

Fourth, to improve the internal validity of the study, a pilot test of the application and the metrics used to collect data could have been conducted. This could potentially have discovered weaknesses in the application and cleared out any confusions raised by the questionnaires used.

7 Conclusion

In this study we have investigated how the use of achievements, leader-board, points, and progress in an mobile application affect students' interest for and attitude towards science. Based on our findings, we argue that these game elements do not have an effect on students' interest and attitude. Looking at the game elements individually, our findings indicate that achievements and leader-board are two factors contributing to the development of interest in science. When these game elements are used in out-of-school science activities, they enhance students interest in science. This study contributes to the scarce literature investigating individual game elements' effects on interest and attitude.

The findings of this study was reached through the development of a mobile application. Its design was grounded in the four-phase model of interest development theory and previous studies on gamification to support our research question. The mobile application was used in a mixed design research experiment combining between- and within-subjects. We explored the research question using qualitative data and methods. The students' interest and attitudes, as well as their intrinsic motivation for game elements, was collected using pre- and post experiment questionnaires. Log and usage data from the mobile application complemented the data collection.

In a broader perspective the study contributes with a preliminary guideline to other researchers on which game elements to investigate further. It also contributes with an indication that game elements' presence' in an educational context can enhance students' interest in science.

7.1 Future work

During our study we have discovered potential future work that could be looked at to inspire future research directions. A future study can use a larger sample size and be longitudinal to further verify the findings of this study. Furthermore, it would be beneficial to run several more experiments to generalize the results to the educational sector. Next, it would be valuable to isolate the game elements and test them to measure their impact on interest in and attitude towards science. As illustrated in wireframes from our prototype (Appendix A), we had plans for a dashboard to isolate game elements. A dashboard would be beneficial in order to isolate user interaction with progress and points. An implementation of a dashboard could also be valuable for the application to improve its metric for game elements, especially for progress and points.

Expanding the application with a dashboard can pave the way for new studies, looking at how a dashboard impacts re-engagement and interest in and attitude towards

science. Longitudinal studies can be conducted to further isolate and test individual game elements and present them as different treatments in different versions of the application. Other expansions of this study are to ground the application's game elements in more intrinsic motivational theory and look at how they affect usage and interest in and attitude towards science. The application can also be expanded with other types of game elements, such as, but not limited to, unlock mechanisms and storyline. Furthermore, we propose to look at science capital's relationship with students' intrinsic motivation for game elements and investigate game elements' effect on science capital.

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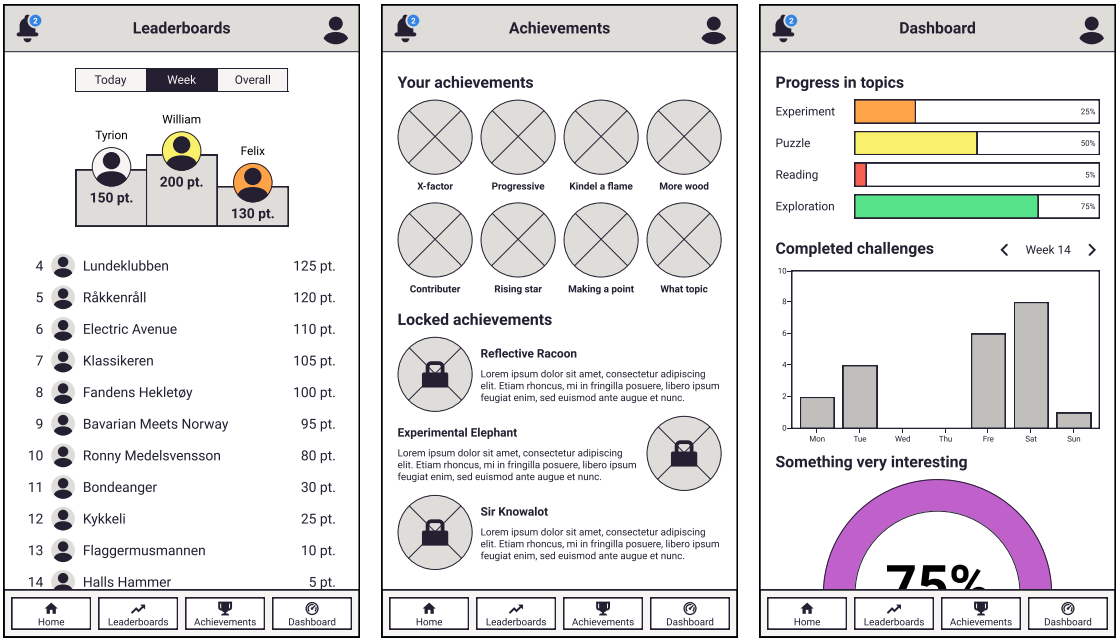
A Application wireframes

This appendix shows a collection of wireframes for our initial prototype made in Figma[1]. Figures A.1 to A.5 illustrates the design for our prototype of the application.



(a) Leaderboards screen **(b)** Achievements screen **(c)** Dashboard screen

Figure A.1: Wireframes for the *Leaderboards*, *Achievements*, and *Dashboard* screens. In the *Leaderboards* screen (Figure A.1a) users are able to see the users' high score of users' for today, the current week, or for the overall use of the application. In the *Achievements* screen (Figure A.1b) users see a list of achievements they have unlocked, as well as currently unlocked achievements. In the *Dashboard* screen (Figure A.1c) users see visual analytics related to their interaction with the application.

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

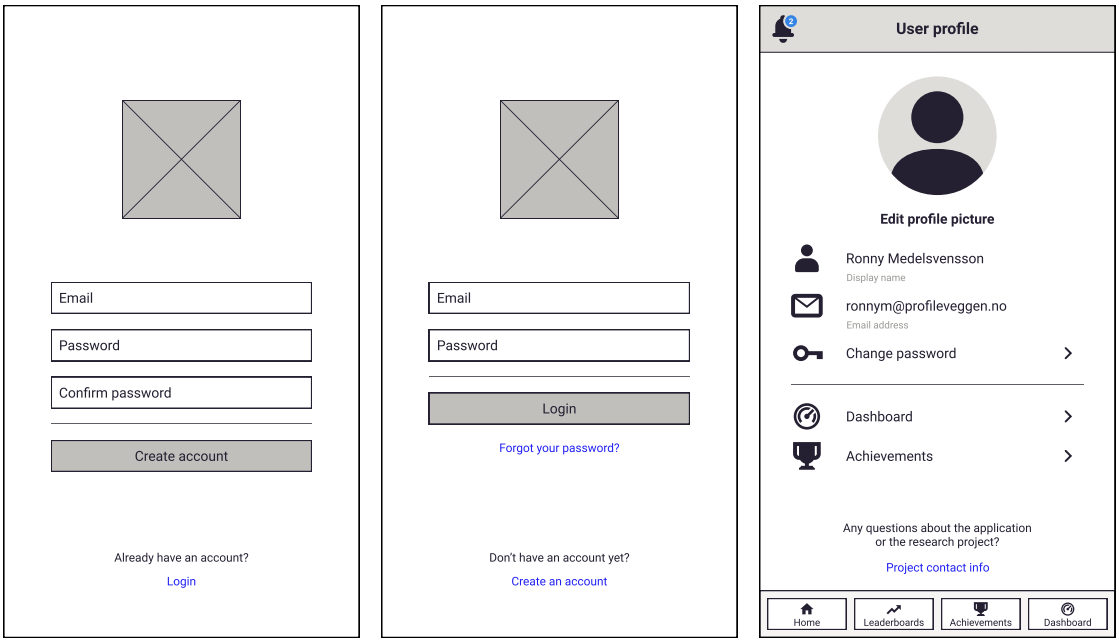


Figure A.2: Wireframes for the *Create account*, *Login*, and *User profile* screens.

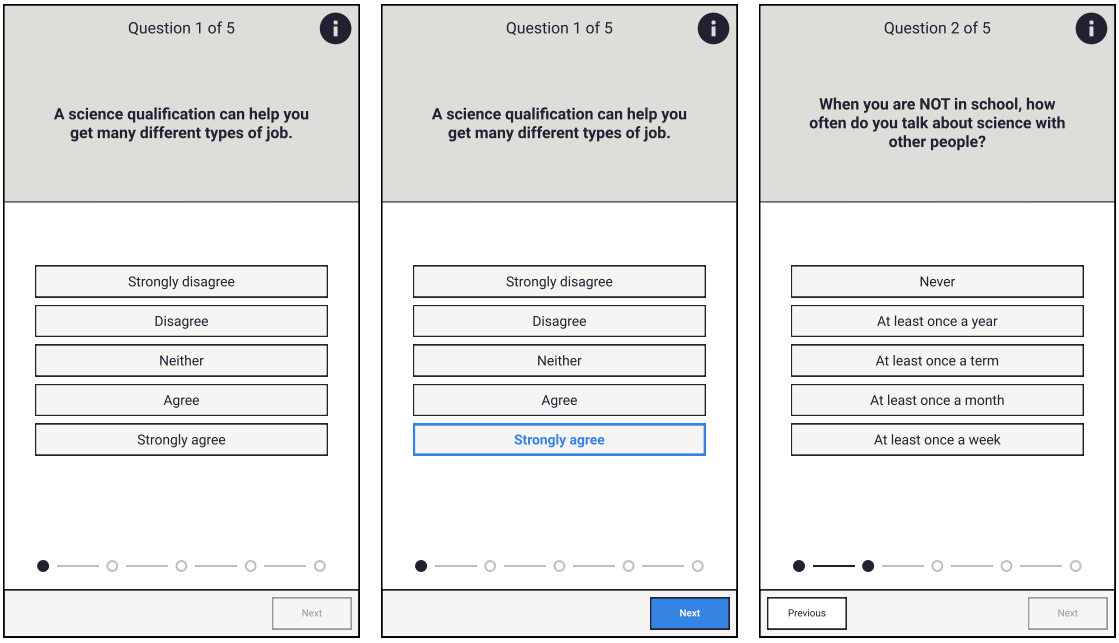
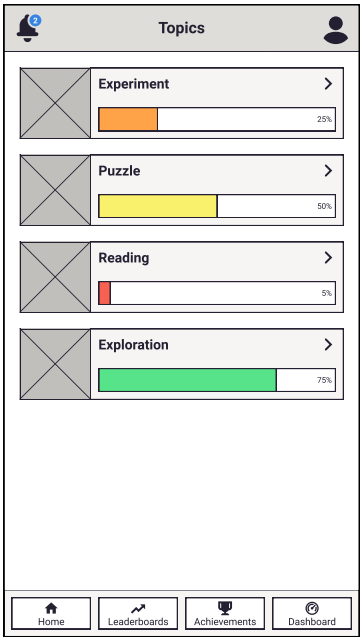
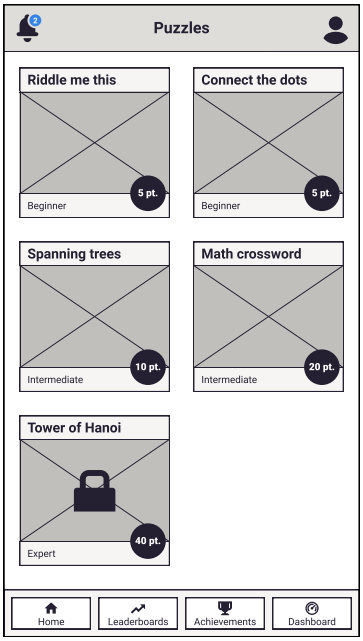


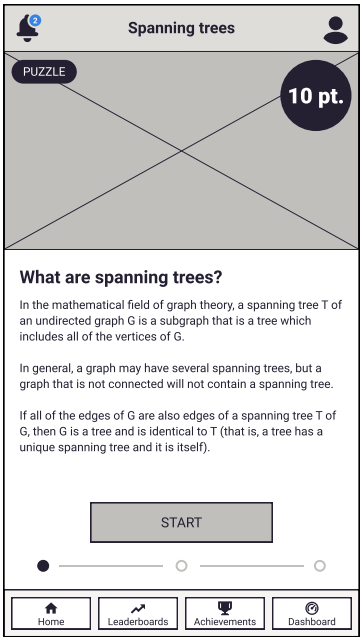
Figure A.3: Wireframes for the in-app questionnaire.



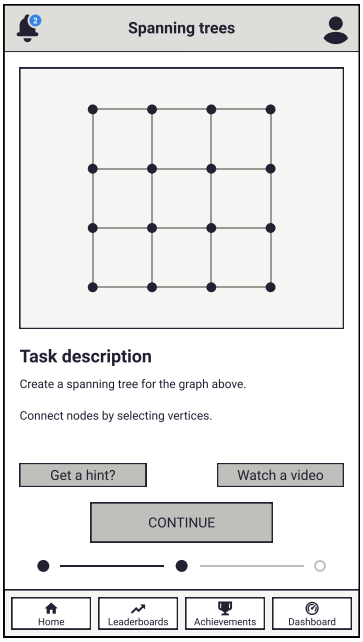
(a) Topics screen



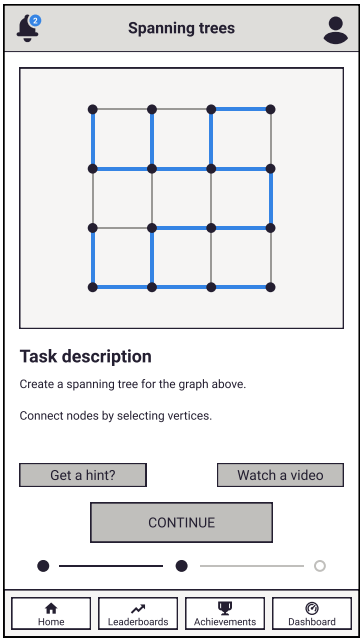
(b) Puzzles screen



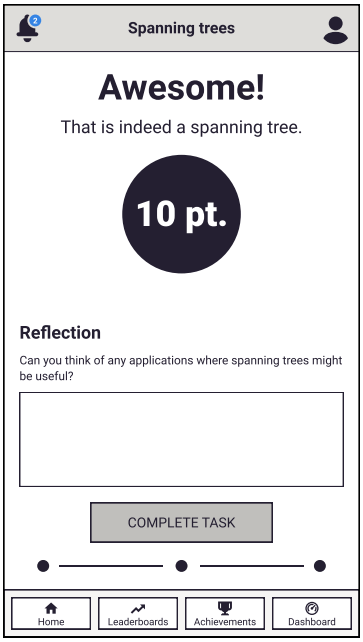
(c) Puzzle step 1



(d) Puzzle step 2

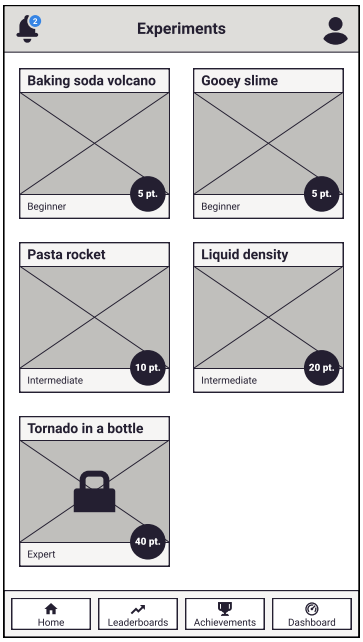


(e) Step 2 after user interaction

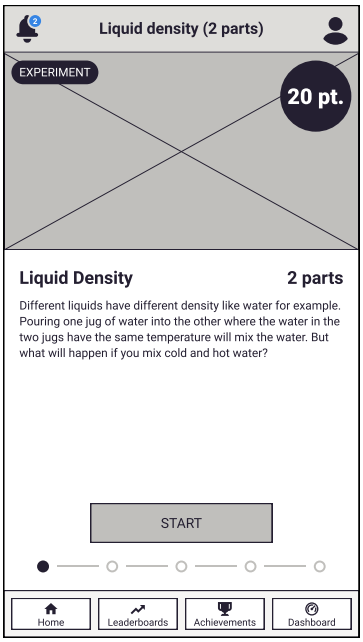


(f) Puzzle step 3

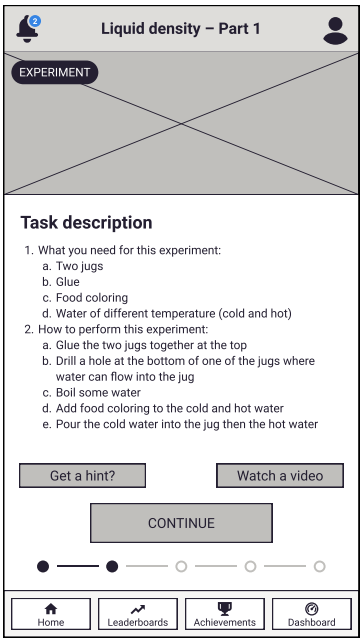
Figure A.4: Wireframes for a puzzle challenge. After selecting *Puzzle* in the *Topics* screen (Figure A.4a) users are presented with a list of available puzzles (Figure A.4b). Figures A.4c to A.4f illustrate the flow of after selecting a puzzle from the list; here exemplified with a *Spanning trees* puzzle.



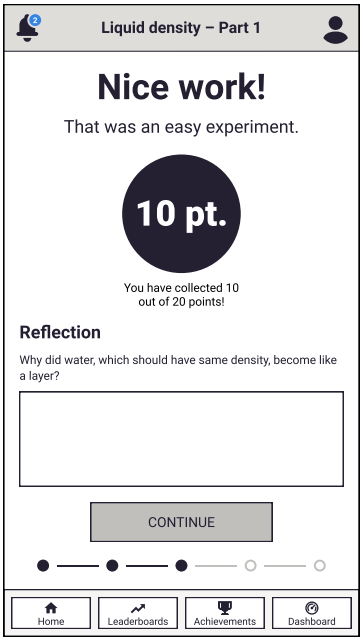
(a) Experiments screen



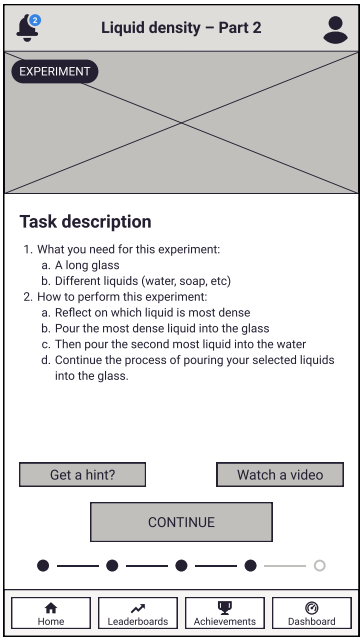
(b) Experiment step 1



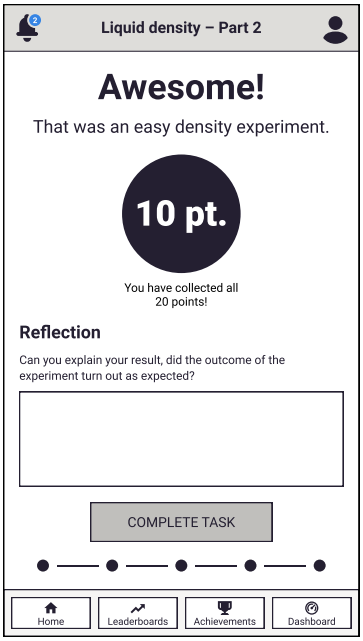
(c) Experiment step 2



(d) Experiment step 3



(e) Experiment step 4



(f) Experiment step 5

Figure A.5: Wireframes for a multipart experiment challenge. After selecting *Experiment* in the *Topics* screen (Figure A.4a) users are presented with a list of available experiments (Figure A.5a). Figures A.5b to A.5f illustrates the flow after selecting an experiment from the list; here exemplified with a two part *Liquid density* experiment.

B Application architecture

In this appendix the application architecture is presented in more detail. It explains the system requirements, elaborate on the architectural design, and presents future expansions for the application.

B.1 System Requirements

To develop the application collecting data for this thesis, a set of prioritized requirements were formed. The requirements were based on literature found (Chapter 2), requirements that could support the finding of an answer to the research question, and the Figma prototype (Appendix A). The functional requirements for the system focus on what functionality the application should provide to the user. Table B.1 shows the requirements for the application and each requirement has an ID, description, and priority. Each groups of IDs, e.g FR1, FR2, FR3, etc, are grouping the requirements into categories. FR1 is requirements related to the user profile, FR2 is related to the categories a challenge belongs to, FR3 addresses the challenges, FR4 states the importance of game elements, FR5 addresses the integration of research methods, FR6 address the game element leader-board, FR7 is related to requirements of logging session activities, FR8 is requirements for logging challenge activity, FR9 addresses logging of button presses in the graphical user interface (GUI), while FR10 extends the previous functional requirement by logging navigation performed by the user, and FR11 is related to assigning user profiles to the different permission groups to facilitate different research designs (Section 4.4). The requirements with a priority of high are the minimum requirements that the application must meet to support the research.

Table B.1: Overview of functional requirements for the application.

ID	Requirement	Priority
FR1	The user should be able to register for an account	High
FR1.1	The user should be able to log in to the application	High
FR1.2	The user should be able to log out from the application	
FR1.3	The user should be able to view their user profile	
FR1.4	The user should be able to update his password	
FR1.5	The user should be able to reset his password	
FR1.6	The user should be able to retrieve data stored about them	High
FR1.7	The user should be able to delete their account	

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Table B.1: Overview of functional requirements for the application (continued).

ID	Requirement	Priority
FR2	The user should be able to see a list of categories	High
FR2.1	The user should be able to see his progress in a specific category	High
FR3	The user should be able to see a list of challenges belonging to a category	High
FR3.1	The user should be able to see the difficulty level of a challenge	High
FR3.2	The user should be able to start a challenge	High
FR3.3	The user should be able to complete a challenge	
FR3.4	The user should be able to get help on completing a challenge	
FR3.5	The user should be able to visit external resources related to a challenge	
FR3.6	The user should be able to reflect on a challenge	
FR3.7	The user should receive points for completing a challenge	
FR3.8	The user should be able to see his progress on a specific challenge	
FR3.9	The user should be able to redo challenges he has completed previously	
FR3.10	The user should not receive points for completing challenges he has completed previously	
FR3.11	The user should be able to vote for other users reflections after a challenge is completed	
FR3.12	The user should be able to see how many times he have completed a given challenge	
FR4	The user should be able to see visualized statistics of his progress in the application	
FR4.1	The user should be able to view achievements	
FR5	The user should be able to answer an in-app questionnaire	High
FR6	The user should be able to view high score leader-boards	
FR7	The application should be able to collect data from a user session	High
FR7.1	The application should be able to log when a user logs in	
FR7.2	The application should be able to log when a user logs out	
FR8	The application should be able to collect data from challenges	High
FR8.1	The application should be able to log when a challenge is started	
FR8.2	The application should be able to log when a challenge is completed	
FR9	The application should be able to collect a user's click stream	High
FR10	The application should be able to log when a user visits a specific screen	
FR11	The application should be able to assign registered users to a group (control or experiment)	High

B.2 Architectural design

This section explains the architectural design and choices taken related to the design of the system. It starts by elaborating on selected architectural views, before the API is presented. It then wraps up the section by explaining how access to the gamified content is restricted.

B.2.1 Architectural views

Architectural views are diagrams used to visualize different parts of the system addressing the concerns of different stakeholders. The architectural views used in this thesis is based on Kruchen's 4+1 architectural view model [63]. The model has four views for visualization.

Logical view Describes the object model of the design.

Process view Captures the concurrency and synchronization aspects of the design.

Physical view Describes the mapping of the software onto the hardware and reflects its distributed aspects.

Development view Describes the static organization of the software in its development environment.

The stakeholders of this project are system engineers, developers, and researchers. The different views addresses the functional requirements of the system. In this appendix, only the logical view and the development view will be used to explain and visualize the architecture.

B.2.2 Development view

According to Kruchten, the development view is *"represented by module and subsystem diagrams that show the system's export and import relationship"*. The component diagram is a part of the development view and visualizes the different components making up the application. The components in this type of diagram represents the different parts of the system which could be developed independently by different development teams, given that they provide an interface to the component other developers could use. The components main features and responsibilities are described in more details when the package diagram is discussed. Figure B.1 show which of the components that exchange data with each other and how the components import and export features from and to each other. It is illustrated by the connectors between each component. The different coloring of the component in the figure is used to group the components, where the yellow color for GUI represents front-end and the orange color represents the back-end part of the system.

To elaborate more on main features and responsibility of different components of the application, the components are turned into package diagrams. The package diagrams are named the same as the components. Each package can include other sub-packages which the package provides to other parts of the system. It is important to point out that some packages are not represented in the implementation, because they are to be considered as future expansions of the application. The packages to be addressed in future expansions are commented on. The package diagrams also includes class

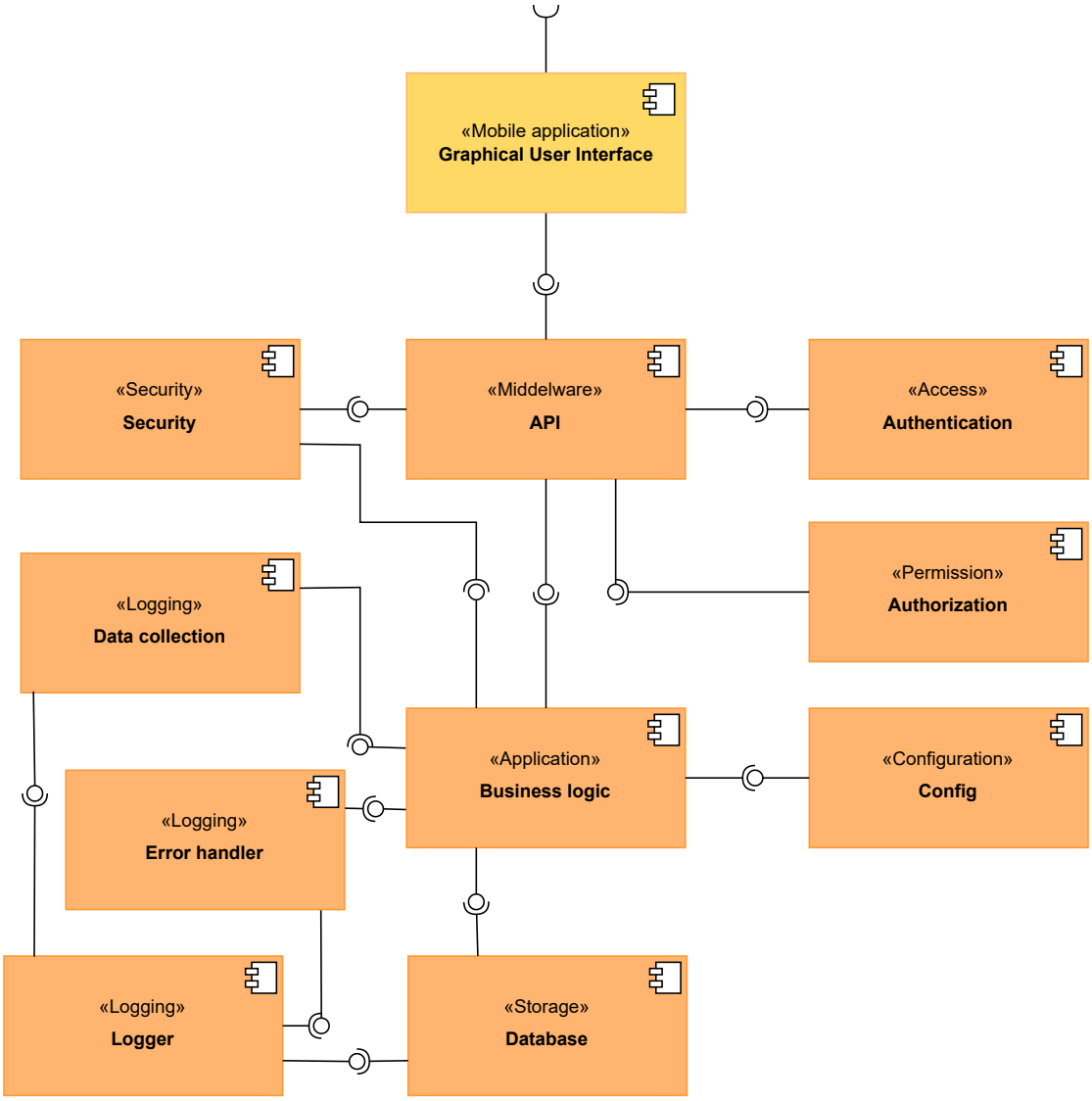

Figure B.1: The component diagram for the system architecture, visualizing the different modules in the system.

diagrams, but these are left out to reduce the complexity of the diagram. Classes provided by each of the packages are further discussed together with the Logical view in section B.2.3. Next, all packages that make up the application are addressed.

API

The *API* has the main responsibility of exchanging data between the GUI and the server where the application is running. Other than exchanging data, the API forward data to other components, such as the business logic, security, authentication, and authorization, to process and act on the data received. The API is the gateway (Figure B.1) for the GUI to trigger features provided by the application's backend, such as validating users, requesting user profile information, and requesting different game elements. To provide such features the API uses the GraphQL framework[1] to provide its services (Figure B.2).

Business Logic

The *Business Logic* package is the core of the application. It is responsible of providing majority of the features specified by the system requirements. The business logic contains the sub-packages (Figure B.2):

1. *Content*, contains the content related classes; activity, category, challenge, content, and reflection.
2. *Analytics*, contains analytical related classes with logic to process and prepare data, collected by the application, for further analysis. See the Extending features section B.3 for more information of how the application is intended to facilitate this feature.
3. *Game elements*, provides classes implementing the logic for the game elements used in the application; achievements, leader-board, progress, and points (Figure B.4).
4. *Profile*, provides the profile related classes with logic defining the data required by a user profile.
5. *Notification*, contains classes used to send notification messages to the user related to actions performed by the system. The messages is related to occurring events in the application, such as achievement rewarded, updates of leader-board, and success messages for actions performed.
6. *Feedback*, is similar to *Notification*, but is messages related to user feedback, such as informing the user about the end of a research period, swapping of permission groups, and reminding users of completing questionnaires. See the Extending features section B.3 for more information of how the application is intended to facilitate this feature.

[1] https://graphql.org/

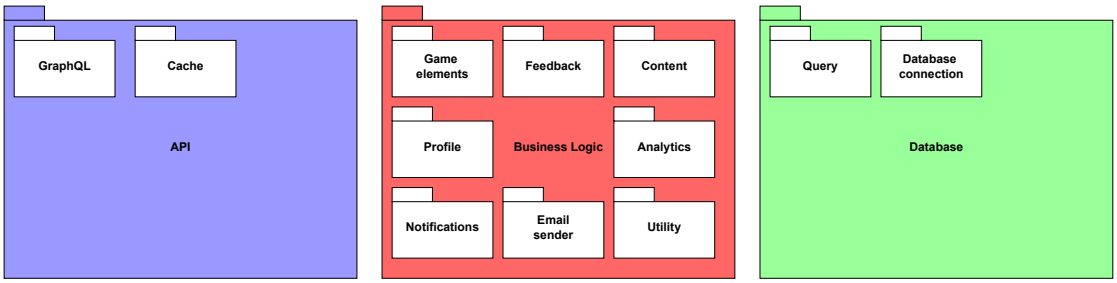

Figure B.2: Package diagrams for the *API*, *Business Logic*, and *Database* packages.

7. *Email sender*, is a package containing logic providing the system a feature to send emails to the users. See the Extending features section B.3 for more information of how the application is intended to facilitate this feature.
8. *Utility*, is a package containing classes taking care of shared logic between the other packages and classes in the *Business logic* package.

Database

The *Database* package contains logic to establish a connection between the application and the database. The application can use the connection to store and retrieve data. If the application in the future are expanded to support multiple database implementations, the following two sub-packages can be included (Figure B.2):

1. *Query*, contains classes for querying the database to store and retrieve data.
2. *Database connection*, contains classes for connecting the server to a database.

Security

The *Security* package (Figure B.3) handles logic related to security measures implemented in the application. The package offers it's services to the API and business logic packages. The package contains two other sub-packages:

1. *Hashing*, handles the security measures related to encryption and decryption of data.
2. *Password*, handles features such as comparing and validating passwords.

Authorization

The *Authorization* package provides features for the system to deal with authorization of users, such as permissions and user sessions (Figure B.3). The features are used by the API package to ensure that the users are logged in and have the correct permission to request data from a restricted endpoint.

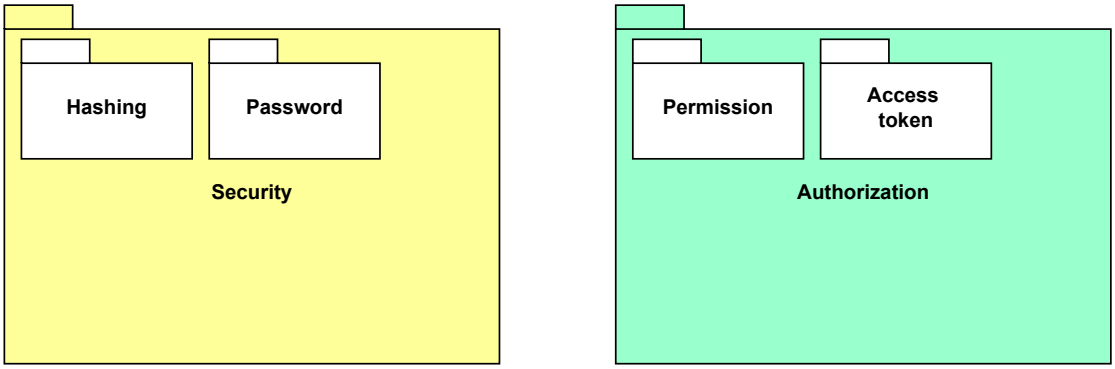

Figure B.3: Package diagrams for the *Security* and *Authenticate* packages.

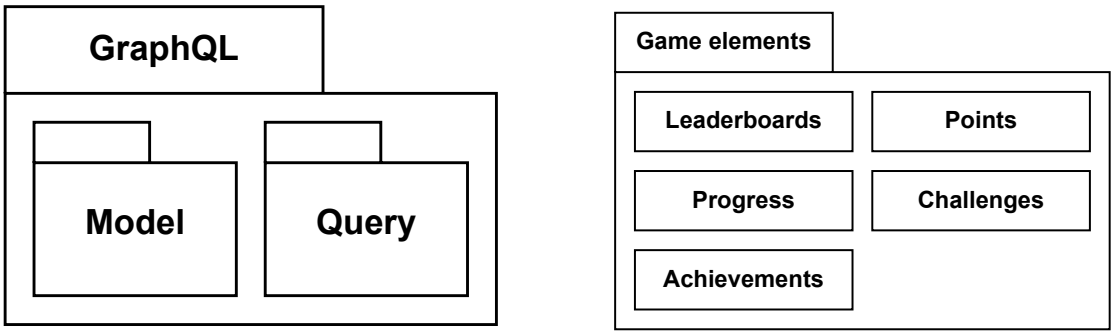

Figure B.4: Package diagrams for the *GraphQL* and *Game elements* packages.

Authentication

The *Authentication* package has the responsibility of making the application able to sign in, sign out and register users for an account. It provides its features to the API package such that the API could enable endpoints for these features to the GUI.

Configuration

The *Config* package is responsible of configure the application settings at start up. The package handles logic defining which mode the server should launch in; production, development or test mode. It defines all environment variables used by other packages. The config package is used by the business logic package (Figure B.1).

Logger

The *Logger* package is responsible of logging data in a given format depending on type of data to log. The features of the logger package is provided to the error handler, data collection, and database packages (Figure B.1). This package can be included in a future expansion of the application to support multiple data formats if needed.

Error Handler

The *Error handler* package is responsible of logging errors occurring in the application. The error handler package is used by the business logic and the logger packages (Figure B.1. See the Extending features section B.3 for more information of how the application is intended to facilitate this feature.

Data collection

The *Data collection* package defines methods for how the application collects and process data needed in research projects. It provides its features to the business logic and the logger packages (Figure B.1).

B.2.3 Logical view

The logical view's main purpose is to illustrate how the classes and their internal working are satisfying the functional requirements. Classes defined are representations of attributes and methods off their corresponding objects. For the application created for this thesis there are 21 classes making up the system (Figure B.5). Each and one of the classes in the application have a responsibility. The individual packages in the architecture have classes as it's core component allowing it to provide it's features.

The profile class diagram, residing in the sub package *Profile* inside the *Business Logic* package, provides profile features. The main purpose of the profile class is to store data for authorization, challenges completed, and accomplished achievements. The methods of a profile and its attributes can be found in Table B.3.

The click stream class diagram is located in the *Data collection* package and contains features logging navigation's performed by the user. Click stream class contributes in collecting useful data to understand how the user engages and re-engage with the content of the application. The click stream data is useful to map the users' interactions with game elements to their effect on other conditions. The click stream class provides features giving insight into users' interaction with the application. The features provided by the click stream class are summarized in Table B.4.

The content class diagram's objective is to support other classes in how to handle what content to render. The content class is part of the *Business Logic* package. It has the responsibility of validating text, such as name and description, and format the content for front-end. The features made available by the content class are shown in Table B.5

The *Business Logic* package contains a sub-package for all the game elements implemented. Game elements supported by the application are achievements, leader-board, progress, and points. The progress game element's class is responsible calculating the user's progress.

The achievement class is responsible for creation of achievements, what conditions must be met to accomplish it, and delete it. It is a static representation of an achievement in the system. There are two types of achievements supported, category and challenges.

Table B.3: Methods and attributes of the Profile class.

Methods	Description
`getPoints`	Retrieves number of points acquired from completing a challenge.
`getPointsByCategory`	Retrieving total number of points acquired for all challenges completed in a given category.
`calculatePoints`	Sums all points acquired from a list of challenges completed.
`changePassword`	Replaces the old password the profile registered with a new password.
`getPermission`	Retrieves the permission assigned to the profile. Permission defines what access the profile has.
`setPermission`	Updates the permission of the profile with a new permission. Could be used to swap a profile's associated treatment group.
`deleteProfile`	Deletes the user's profile and data associated with it.
`requestUserData`	Sends a message from the user to the administrator requesting to receive and view data collected for their profile by the application.
Attribute	**Description**
`userID`	A unique id associated with the profile as a string.
`email`	The email address of the participating user. It could be used to get in touch with participants or support forgotten password feature.
`password`	A user defined password as a string used to authenticate the user.
username	A unique username which could be pre-defined for a research project or created by the user themselves.
`permission`	An integer representing the permission level of the profile. Defines what features the profile has access to. Could be randomly assigned during profile creation or pre-assigned for more granular control over research designs.
`achievements`	A list of achievements the user has accomplished.
`challenges`	A list of challenges the user has completed.
`progress`	A hash-map measuring the progress for each achievement and challenge offered by the application.
`state`	The current operational state of the profile. An integer defining if a profile is active, deactivated, or suspended. A profile starts as deactivated and becomes active when a user register or activates an account. A profile could be suspended by an administrator if the user violates guidelines for the participation or withdraws from participating.

Table B.4: Methods and attributes of the ClickStream class.

Method	Description
`addClickEvent`	Logs data for navigation between two screens or buttons interacted with.
`addDeviceInfo`	Logs the phone model and other device specific data.
Attribute	**Description**
`id`	A unique id as a string associated with the click stream.
`userID`	A unique identifier as a string associated with the profile the click stream belongs to.
`sessionToken`	A unique identifier for the ongoing session of the user. This token is the same as the refresh token the user is granted when logged in.
`deviceInfo`	A hash-map containing information about the device used.
`clicks`	A list of hash-map objects storing the navigation and clicks performed by the user in the application.

Table B.5: Methods and attributes of Content class.

Method	Description
`setName`	Updates the name of the content to a new name.
`setImage`	Updates the image with a new image or an URL of an image.
`setDescription`	Updates the description of the content with a new description.
Attribute	**Description**
`name`	The name of the content as a string.
`image`	The image to be rendered with the content.
`description`	A descriptive text for the content as a string.

Table B.6: Methods and attributes of Category class.

Method	Description
`updateCategory`	Updates fields of category object with new data.
`addChallenge`	Add a new challenge to the category.
`removeChallenge`	Remove an existing challenge from the category.
`deleteCategory`	Delete category from database.
Attribute	**Description**
`id`	A unique identifier as a string for the category.
`content`	A reference to the content class giving this class access to the content class object and its features.
`challenges`	A list of challenges belonging the category.

Category achievements are awarded if all challenges within a category are completed, while challenge achievements are awarded for individual challenges completed. The user achievement class is a copy of the achievement class, and has some other attributes and features. It is awarded to the user when an achievement is accomplished. It allows the system to change the original achievement's content without affecting achievements already awarded.

The leader-board class responsibility is to calculate a high score leader-board from the registered profiles' in the application. It could be expanded to calculate other types of leader-boards, such as a leader-board for categories. An application facilitating the use of a leader-board must facilitate the use of points to calculate a rank for the user. The points class defines how many points each challenge award. The points awarded could be differentiated based on the difficulty level of a challenge.

The challenges a user can do are divided into categories. The category class maintains a collection of challenges belonging to the category. The class maps rendering of challenges for the category selected. The features of the category class are summarized in Table B.6

The challenges are the main content of the application and are activities the users' can complete. The challenges are descriptive content providing a step by step guide on how to do science activities. They award points and achievements when they are completed. Every completed challenge updates the progress of the category the challenge belongs to and updates the leader-board with a new score. It is the challenge class main responsibility of providing such features. The challenge class reference other classes to delegate relevant tasks to features provided by them. Even though the challenge class is one of the most important classes for the application to provide content, it only has two features as shown in Table B.7:

As part of the challenge class are other classes such as reward, reflection, and activity. These classes makes up partially the business logic of the challenge class and offers their features to it. The responsibility of the reward class is to store how many points are

Table B.7: Methods and attributes of Challenge class.

Method	Description
`updateChallenge`	updates the challenge data with the provided data.
`deleteChallenge`	deletes the challenge from the database.
Attribute	**Description**
`id`	a unique identifier as a string for the challenge.
`content`	a reference to the content class giving this class access to the content class object and its features.
`activity`	a reference to the activity class giving this class access to the activity class object and its features.
`reflection`	a reference to the reflection class giving this class access to the reflection class object and its features.
`category`	a reference to the category class and what category this challenge should be added to.
`reward`	a reference to the reward class giving this class access to the reward class object and its features
`difficulty`	the difficulty level as a number representing how difficulty the challenge is.

awarded for the challenge. The user can be awarded three types of points: points for first try, points for completing the challenge, and bonus points for answering correct on first try. The first try points are always rewarded regardless of performance and is meant to be a motivational boost. Completing the challenge, giving a correct answer, and reflect on the challenge, rewards the max points for the challenge. Regardless of total attempts performed to complete the challenge, the max points are rewarded if they have not been awarded before. Zero points are awarded if a user already has been awarded the max points and is implemented to mitigate shopping of points to climb the leader-board. The bonus points are awarded if the user completes a challenge and provides a correct answer the first time they try the challenge.

The reflection class allows users to reflect on the challenge by presenting questions related to the challenge. The reflection could be one of two types; free reflection or argument reflection. The free reflection presents the user open ended questions with no right or wrong answers, allowing the user to reflect on the activity they have conducted. The argument reflection presents the user with words they must combine into a valid argument, requiring the user to understand the learning aspect of the challenge.

How to do the challenge is presented by the activity class. The activity is a static presentation and presents what to do for the activity through a description. A further expansion of this class is to support different types of activities in the application, such as interactive challenges. The activity include resources and hints, providing users' with external resources supporting them in completing the challenge.

To preserve the correct information for a challenge a user has completed at any given

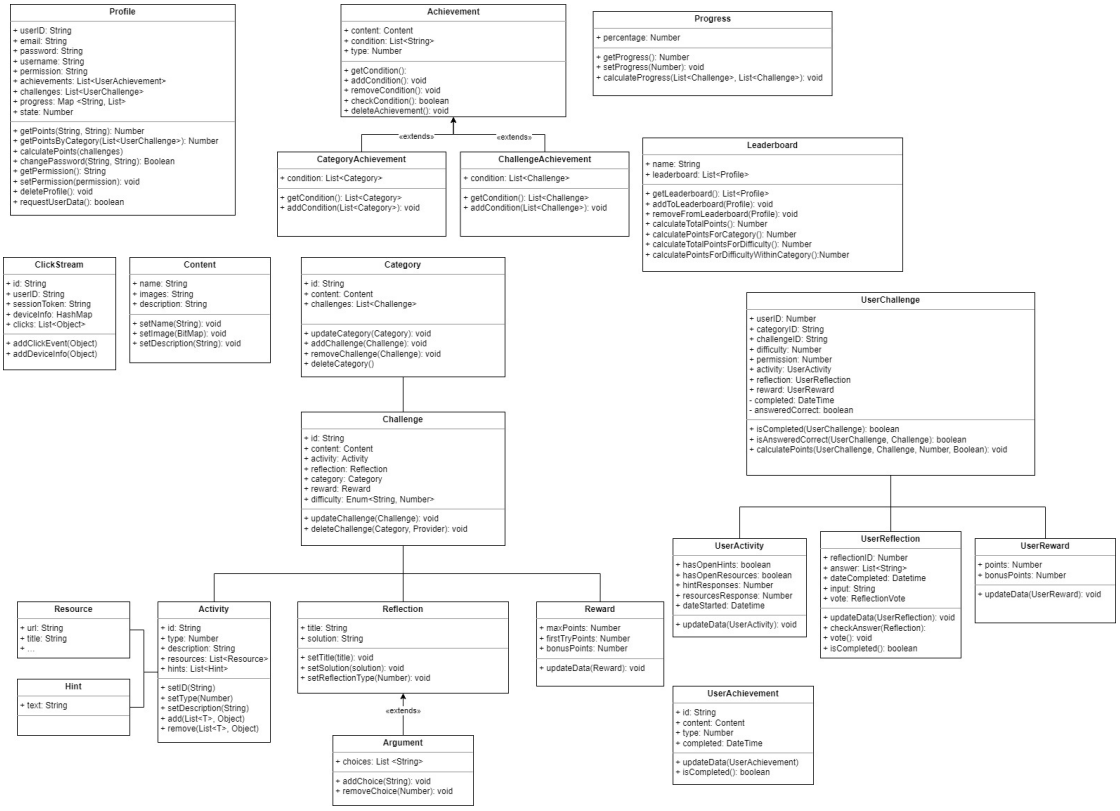

Figure B.5: The class diagram for the system architecture, showing an overview of the classes, their features and attributes, and the relationship between them.

time, the user must store a replication of the challenge object. It prevents data about the challenge to be lost if a challenge is updated with information. Therefore, the *UserChallenge*, *UserReward*, *UserReflection*, *UserActivity*, and *UserAchievement* exists. The main purpose of these classes are to replicate data from their static counterparts and log data specific for the user. More specific data related to each individual user for the *UserChallenge* are the permission level they had when they completed the challenge, the reward obtained, the reflection, completion date, and if it was answered correct. Features and attributes for each of the replication classes could be found in Figure B.5.

B.2.4 Application programming interface

In order to make our server able to exchange data with other servers or devices, it implements an application programming interface (API) which they can use to exchange data. An API can provide a single or multiple endpoints to expose features of an application which can be triggered by devices implementing the endpoints. For this application, the API was implemented using the GraphQL framework. GraphQL is a query language for APIs, that enabled the client to request a set of data offered by the

Table B.8: Overview of GraphQL query endpoints exposed by the application.

Endpoint	Description	Permission
`accessToken`	Authenticates the refresh token of a user to verify if a user's session is valid. Returns new access token if user session is expired	all
`achievements`	Retrieves all achievements available	experiment
`categories`	Retrieves all categories available	all
`challenges`	Retrieves all challenges available in all categories	all
`clickStreams`	Retrieves all click streams available for all users	admin
`contacts`	Retrieves the contact information of the researchers responsible	all
`leaderboards`	Retrieves the high score leader-board	experiment
`permissions`	Retrieves the permission levels supported	admin
`userProfile`	Retrieves the profile information for the user	all
`verifyToken`	Checks if an access token is still valid	all
`verifyUsername`	Checks if username is valid and authorized to create a profile	all

API if the client specify the data it want in the request. Instead of returning all the data in the request, like APIs implemented with Express-framework does, it returns exactly what it is asked for. The framework make the implementation of the GUI less complex as it only receives data it will use. It make the implementation of the API on the server-side less complex as multiple endpoints are not needed to provide the client with a minimal set of data it needs.

The main purpose of the API provided by our server is to offer the features of the application to the client-side, exchange data between the client and the server, and forward the data from the client to the business logic providing the requested feature. GraphQL defines three *types* for reading and writing data: (i) Query, (ii) Mutation, and (iii) Subscription. The Query type is used for reading data, and is equivalent to a GET request in a traditional representational state transfer (REST) API. The Mutation type is used for writing and updating data, and is equivalent to POST, PUT, and DELETE requests in REST APIs. The Subscription type enables clients to subscribe to data updates, and is typically triggered after a mutation-request. An update causes the subscription endpoint to push data to all clients subscribed to the endpoint. Endpoints and features exposed by the API are listed in Tables B.8 to B.10.

B.2.5 Restricting access to the gamified content

In order for our API to support multiple versions of the application, the API is restricted with permission levels. The different permission levels supported by the application are control, experiment, and admin. That means that the different users have a permission level associated with their user profile restricting which endpoints and data they can request. Based on the permission required, a single implementation can support a

Table B.9: Overview of GraphQL mutation endpoints exposed by the application.

Endpoint	Description	Permission
`activateAccount`	Activates a verified profile by updating the profile state to active	all
`addContact`	Add new person to the list of contacts responsible for the application	admin
`addUserChallenge`	Adds a new user challenge object to the user profile when a user completes a challenge	all
`addUserChallengeRating`	Adds a rating given by the user when challenge is completed	all
`changePassword`	Updates the profile of a user with a new password defined by the user	all
`createAchievement`	Create new achievement for the application	admin
`createCategory`	Create new category for the application	admin
`createChallenge`	Create new challenge for the application	admin
`deleteClickStream`	Delete click stream with a given id from database	admin
`deleteUserChallenge`	Delete user challenge with a given id from database	admin
`logDeviceInfo`	Logs device information	all
`logEvent`	Logs a new click stream event if click stream already exists for the user's session	all
`setPermission`	Updates a single user's permission by id	admin
`signIn`	Sign in the user to their profile and creates a new session	all
`signOut`	Sign out the user from their profile and terminate the session	all
`swapPermissionGroup`	Swaps all the profiles permissions from control to experiment and vice versa. Profiles with admin permission is unaffected	admin

Table B.10: Overview of GraphQL subscription endpoints exposed by the application.

Endpoint	Description	Permission
`leaderboards`	Subscribes a user to leader-board updates	experiment
`swappedPermission`	Subscribes a user to a notification when their permission group is swapped	admin
`userChallengeAdded`	Subscribes a user to updates when a user challenge is completed	all

control and experimental version by switching game elements on or off. The permission of control exposes the features without game elements enabled, while experiment enables the game elements. The switching of permissions is done sending a request to the `swapPermissionGroup` endpoint (Table B.9) by an administrator of the application. Introducing a permission system to take care of the the different versions eliminates the need for implementing two separate versions of the application. It also reduces the complexity of executing the research design, as the participants does not need to uninstall one version and install another.

B.3 Extending the application

The application could be further extended with new features that could support other research designs, answering other research questions, and make the application more versatile for other purposes. The first feature the application could benefit from is the implementation of an analytical module. The main purpose for such a module is to read and process log and usage data. Implementing such a module could support other researchers using the application in converting data into useful metrics for statistical analysis. It will potentially save time for researchers as every new research project does not have to implement their own way of processing the data.

A second feature could be a feedback module with a purpose of notifying users about the state and progress of the research. This could be a welcome messages with a notice of what treatment group they belong to, how much time is left until the project ends, when groups are swapped, and which questionnaire should be answered. The feedback module could also be used to notify users about successful and unsuccessful actions performed in the application.

A third feature to implement is an email sender module. The main purpose of such a module is to integrate the application with an SMTP service such that the system can send automatic emails to the users participating in the research. Such emails could be used to inform users about the research progress, timeline, and activities involved in the project. If the application is extended to allow users to create and register new accounts, the ability to send emails would be crucial in order for users to be able to reset forgotten passwords. This feature could lessen the burden for researchers in large scale research projects because there is less need for monitoring requests from participants and manually inform them about the state of the research.

A fourth feature is an error handler module that logs all errors occurring in the application. Such a module could help the development team to keep track of important errors that must be addressed. It could also discover potential conditions of the implementation that are not tested properly. An error handler module could help developers to react and mitigate faults that could harm the collection of data for the research.

A fifth feature strengthening the data collection for the research is a profile dashboard. The profile dashboard could visualize metrics to the user and isolate the different game

elements into individual views. Isolating game elements would allow the application to log more specific data about each game element. The game elements progress and points would benefit from such an implementation, as they are usually used to enhance other views and, therefore, hard to measure and collect data for.

C Information letter

Vil du delta i forskningsprosjektet *Ungdoms interesse og holdning til naturvitenskap*?

Dette er et spørsmål til deg om å delta i et forskningsprosjekt hvor formålet er å undersøke hvordan spillelementer påvirker ungdoms interesse for og holdning til naturvitenskap og forskning. I dette skrivet gir vi deg informasjon om målene for prosjektet og hva en deltakelse i prosjektet vil innebære for deg.

Formål

Dette forskningsprosjektet gjennomføres som del av en masteroppgave ved Institutt for datateknologi og informatikk ved NTNU i Trondheim. Formålet med prosjektet er å undersøke hvordan bruken av spillelementer i en mobilapplikasjon kan være med på å påvirke ungdoms interesse for og holdning til naturvitenskap og forskning.

Hvem er ansvarlig for forskningsprosjektet?

Sofia Papavlasopoulou, førsteamenuensis ved Institutt for datateknologi og informatikk ved NTNU i Trondheim er ansvarlig for forskningsprosjektet. I tillegg er det masterstudentene Andreas Naterstad Digernes og Einar Uvsløkk, ved samme institutt, som jobber med forskningsprosjektet.

Hvorfor får du spørsmål om å delta?

Du får spørsmål om å delta i dette forskningsprosjektet fordi du er elev på en videregående skole.

Per dags dato har vi ingen informasjon om deg, men vi har tatt kontakt med din skole og forhørt oss om dette kunne være interessant for deg å delta på.

På siste side finner du et samtykkeskjema som du kan skrive under på hvis du ønsker å delta. Om du er yngre enn 18 år må i tillegg en av dine foresatte skrive under på samtykket.

Gir du ditt samtykke vil vi kontakte deg og gi deg tilgang til å delta i eksperimentet.

Hva innebærer det for deg å delta?

Hvis du har lyst til å delta i forskningsprosjektet, vil vi først at du svarer på spørsmål i et spørreskjema. Spørsmålene vil handle om din relasjon til naturvitenskap og forskning.

Du vil deretter få tilgang til en mobilapplikasjon som du kan installere på din smarttelefon. I mobilapplikasjonen får du mulighet til å gjennomføre ulike naturvitenskaplige aktiviteter. Vi vil samle inn ulike data fra din bruk av mobilapplikasjonen. Dette inkluderer data relatert til din progresjon og ditt bruksmønster i applikasjonen.

Selve gjennomføringen av eksperimentet vil foregå i to deler. I hver del får du tilgang til én versjon av mobilapplikasjonen, og du får mulighet til å bruke applikasjonen i en gitt periode. Hver del avsluttes med at du svarer på noen spørsmål i et nytt spørreskjema. Disse spørsmålene vil handle om hvordan du opplevde bruken av applikasjonen.

Det er frivillig å delta

Det er frivillig å delta i prosjektet. Hvis du velger å delta, kan du når som helst trekke samtykket tilbake uten å oppgi noen grunn. Alle dine personopplysninger vil da bli slettet. Det vil ikke ha noen negative konsekvenser for deg hvis du ikke vil delta eller senere velger å trekke deg.

Ditt personvern – hvordan vi oppbevarer og bruker dine opplysninger

Vi vil bare bruke informasjon om deg til å finne ut hvordan bruken av spillelementer i en mobilapplikasjon kan være med på å påvirke ungdoms interesse for og holdning til naturvitenskap og forskning.

Vi vil ikke dele din informasjon med andre. Det er kun prosjektgruppen som har tilgang til dine personlige data. Følgende forskere er med i prosjektgruppen: Andreas Naterstad Digernes og Einar Uvsløkk. Følgende veiledere er med i prosjektgruppen: Sofia Papavlasopoulou, Kshitij Sharma, og Michail Giannakos. Vi passer på at ingen kan få tak i informasjonen som vi samler inn om deg. All informasjon blir lagret på ett sikkert sted. Vi passer på at du ikke kan identifiseres i oppgaven som omhandler forskningen. Vi følger loven om personvern.

Vi vil bare bruke opplysningene om deg til formålene vi har fortalt om i dette skrivet. Vi behandler opplysningene konfidensielt og i samsvar med personvernregelverket.

Hva skjer med opplysningene dine når vi avslutter forskningsprosjektet?

Opplysningene dine vil bli anonymiseres når forskningsprosjektet avsluttes 6. juni, 2022.

Hva gir oss rett til å behandle personopplysninger om deg?

Vi behandler opplysninger om deg basert på ditt samtykke.

På oppdrag fra Institutt for datateknologi og informatikk ved NTNU i Trondheim har NSD – Norsk senter for forskningsdata vurdert at behandlingen av personopplysninger i dette prosjektet er i samsvar med personvernregelverket.

Dine rettigheter

Så lenge du kan identifiseres i datamaterialet, har du rett til:

- innsyn i hvilke opplysninger vi behandler om deg,
- å få rettet opplysninger om deg som er feil eller misvisende,
- å få slettet personopplysninger om deg,
- å få utlevert en kopi av opplysningene om deg, og
- å sende klage til Datatilsynet om behandlingen av dine personopplysninger.

Kontaktinformasjon

Hvis du har spørsmål til studien, eller ønsker å vite mer om eller benytte deg av dine rettigheter, kan du ta kontakt med prosjektleder:

Sofia Papavlasopoulou
Førsteamanuensis
Institutt for datateknologi og informatikk
NTNU, Trondheim
Epost: spapav@ntnu.no
Telefon: +47 457 86 588

eller en av masterstudentene:

Andreas Naterstad Digernes
Master student
Institutt for datateknologi og informatikk
NTNU, Trondheim
Epost: andrend@stud.ntnu.no
Telefon: +47 908 59 158

Einar Uvsløkk
Master student
Institutt for datateknologi og informatikk
NTNU, Trondheim
Epost: einaru@stud.ntnu.no
Telefon: +47 476 45 638

Du kan også ta kontakt med personvernombudet ved NTNU:

Thomas Helgesen
Email: thomas.helgesen@ntnu.no
Telefon: +47 930 79 038

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

NSD – Norsk senter for forskningsdata AS
Epost: personverntjenester@nsd.no
Telefon: +47 53 21 15 00

Med vennlig hilsen

(Prosjektleder)	(Master student)	(Master student)

Samtykkeerklæring

Jeg har mottatt og forstått informasjon om prosjektet *Ungdoms interesse og holdning til naturvitenskap*, og har fått anledning til å stille spørsmål.

Jeg samtykker til å delta i eksperimentet og å svare på spørreskjema.

Jeg samtykker til at mine opplysninger behandles frem til prosjektet er avsluttet.

(Signert av prosjektdeltaker, dato)

Samtykke fra foresatte for deltakere under 18 år

Jeg har lest og forstått informasjonen om prosjektet *Ungdoms interesse og holdning til naturvitenskap*.

Jeg samtykker til at _____ kan delta i eksperimentet og svare på spørreskjema, samt at vedkommendes opplysninger behandles frem til prosjektet er avsluttet.

(Signert av foresatte, dato)

D Pre questionnaire

Spørreskjema 1 – Ungdoms interesse og holdning til naturvitenskap

Dette spørreskjemaet tar omtrent 10 minutter å gjennomføre.

Spørreskjemaet er en del av et forskningsprosjekt, hvor formålet er å undersøke hvordan spillelementer påvirker ungdoms interesse for og holdning til naturvitenskap og forskning.

Hvis du har spørsmål angående spørreskjemaet kan du ta kontakt via e-post til einaru@stud.ntnu.no eller andrend@stud.ntnu.no.

Personopplysninger

1. Brukernavn du har fått utdelt

2. Hvilken aldersgruppe tilhører du?

- ❍ yngre enn 15 år
- ❍ 15 – 16 år
- ❍ 16 – 17 år
- ❍ 17 – 18 år
- ❍ 18 – 19 år
- ❍ eldre enn 19 år

3. Hvilen klassetrinn tilhører du?

- ❍ 1. klasse
- ❍ 2. klasse
- ❍ 3. klasse
- ❍ 4. klasse
- ❍ Påbygg
- ❍ Annet

4. Hvilket kjønn identifiserer du deg som?

- ❍ Mann
- ❍ Kvinne
- ❍ Ikke-binær
- ❍ Ønsker ikke å svare

Vitenskapskapital

Her ønsker vi å kartlegge din vitenskapskapital (science capital).

Din vitenskapskapital sier noe om hva du vet og tenker om vitenskap, samt hvem du kjenner som har en forståelse av vitenskap.

5. I hvor stor grad er du enig i de følgende påstandene?

	Svært uenig	Uenig	Både-og	Enig	Svært enig
En naturvitenskapelig kvalifikasjon kan hjelpe meg med å få mange forskjellige typer jobber	❍	❍	❍	❍	❍
En eller begge av mine foreldre synes vitenskap er veldig interessant	❍	❍	❍	❍	❍
En eller begge av mine foreldre har forklart meg at vitenskap er nyttig for fremtiden min	❍	❍	❍	❍	❍
Jeg vet hvordan jeg bruker vitenskapelig bevis for å argumentere	❍	❍	❍	❍	❍
Lærerne mine har spesifikt oppfordret meg til å fortsette med realfag etter videregående	❍	❍	❍	❍	❍
Lærerne mine har forklart meg at realfag er nyttig for fremtiden min	❍	❍	❍	❍	❍
Det er nyttig å kunne vitenskap i hverdagen	❍	❍	❍	❍	❍

6. Vitenskapelig eksponering utenfor skolen

	Aldri	Minst én gang i året	Minst én gang i halvåret	Minst én gang i måneden	Minst én gang i uken
Når du ikke er på skolen, hvor ofte leser du bøker eller blader om vitenskap?	❍	❍	❍	❍	❍
Når du ikke er på skolen, hvor ofte besøker du et vitenskapssenter, vitenskapsmuseum, eller planatarium?	❍	❍	❍	❍	❍
Når du ikke er på skolen, hvor ofte besøker du en dyrehage eller et akvarium?	❍	❍	❍	❍	❍
Hvor ofte går du på vitenskapsklubber etter skoletid?	❍	❍	❍	❍	❍
Når du ikke er på skolen, hvor ofte snakker du om naturfag med andre mennesker?	❍	❍	❍	❍	❍

7. Hvem snakker du med om vitenskap?

- ❑ Foreldre eller foresatte
- ❑ Slektninger
- ❑ Venner
- ❑ Søsken
- ❑ Direkte med forskere
- ❑ Lærere

8. Kjenner du noen som jobber med naturvitenskap?

- ❑ Foreldre eller foresatte
- ❑ Slektninger
- ❑ Venner
- ❑ Søsken
- ❑ Ingen

Naturvitenskapelige aktiviteter på fritiden

Her ønsker vi å finne ut hvor mye tid du benytter på fritiden til å oppsøke naturvitenskapelig innhold.

9. Vitenskapelig eksponering utenfor skolen

	Aldri	Minst én gang i året	Minst én gang i halvåret	Minst én gang i måneden	Minst én gang i uken
Hvor ofte engasjerer du deg i vitenskapelige aktiviteter eller samhandler med vitenskapsrelatert innhold på fritiden?	❍	❍	❍	❍	❍
Hvor ofte ser du på vitenskapsrelatert innhold på internett? (F.eks. Youtube, TikTok, Instagram, etc.)	❍	❍	❍	❍	❍
Hvor ofte søker du på internett etter vitenskapelig innhold? (Vitenskapsmagasiner, nettsteder som presenterer eksperimenter osv.)	❍	❍	❍	❍	❍

10. Har du planer om å engasjere deg i flere vitenskapsrelaterte aktiviteter i fremtiden?

❍ Ja
❍ Nei

11. Har du engasjert deg i vitenskapelige aktiviteter du planla for de siste to månedene?

❍ Ja
❍ Nei

12. Har du prøvd ut vitenskapelige eksperimenter på egen hånd de siste to månedene?

❍ Ja
❍ Nei

Mestringsevne

Her ønsker vi å finne ut hvordan du oppfatter din egen mestringsevne angående naturvitenskap.

13. I hvor stor grad er du enig i de følgende påstandene?

	Svært uenig	Uenig	Både-og	Enig	Svært enig
Jeg anser meg selv som en ekspert innen naturvitenskap	❍	❍	❍	❍	❍
Jeg gjør det bra i undervisning som tar for seg naturvitenskap	❍	❍	❍	❍	❍
Jeg har mye kunnskap om vitenskap	❍	❍	❍	❍	❍
Jeg kan forklare hvorfor noe skjer og hva som skjer i naturvitenskapelige eksperimenter	❍	❍	❍	❍	❍
Jeg kan knytte kunnskapen jeg lærer fra naturvitenskap opp mot kunnskap jeg allerede har	❍	❍	❍	❍	❍
Jeg føler meg trygg på å samle og prosessere naturvitenskapelig data	❍	❍	❍	❍	❍
Jeg føler meg trygg på å bruke vitenskapelige metoder	❍	❍	❍	❍	❍
Jeg føler meg trygg på å bruke vitenskap til å løse problemer	❍	❍	❍	❍	❍

Holdning

Her ønsker vi å kartlegge din holdning til naturvitenskap og forskning.

14. I hvor stor grad er du enig i de følgende påstandene?

	Svært uenig	Uenig	Både-og	Enig	Svært enig
Vi lærer interessante ting i realfagstimene	❍	❍	❍	❍	❍
Jeg ser frem til realfagstimene mine	❍	❍	❍	❍	❍
Naturvitenskap er spennende	❍	❍	❍	❍	❍
Jeg ville likt å gjøre mer naturvitenskap på skolen	❍	❍	❍	❍	❍
Jeg liker realfag bedre enn mange andre fag på skolen	❍	❍	❍	❍	❍
Naturvitenskap er kjedelig	❍	❍	❍	❍	❍
Jeg synes naturvitenskap er vanskelig	❍	❍	❍	❍	❍
Jeg er ikke flink i naturvitenskap	❍	❍	❍	❍	❍
Jeg får gode karakterer i naturvitenskap	❍	❍	❍	❍	❍

Continues on next page...

	Svært uenig	Uenig	Både-og	Enig	Svært enig
Jeg lærer vitenskap raskt	❍	❍	❍	❍	❍
Realfagsemner er det jeg gjør det best i	❍	❍	❍	❍	❍
Jeg føler meg hjelpeløs når jeg driver med vitenskap	❍	❍	❍	❍	❍
I realfagstimene forstår jeg alt	❍	❍	❍	❍	❍
Praktisk arbeid i realfag er spennende	❍	❍	❍	❍	❍
Jeg liker vitenskapelig praktisk arbeid fordi man ikke vet hva som vil skje	❍	❍	❍	❍	❍
Praktisk arbeid i realfag er bra fordi jeg kan jobbe med vennene mine	❍	❍	❍	❍	❍
Jeg liker praktisk arbeid i realfag fordi jeg kan bestemme hva jeg skal gjøre selv	❍	❍	❍	❍	❍
Jeg vil gjerne ha mer praktisk arbeid i realfagstimene mine	❍	❍	❍	❍	❍
Vi lærer realfag bedre når vi gjør praktisk arbeid	❍	❍	❍	❍	❍
Jeg ser frem til å gjøre realfag	❍	❍	❍	❍	❍

15. I hvor stor grad er du enig i de følgende påstandene?

	Svært uenig	Uenig	Både-og	Enig	Svært enig
Praktisk arbeid i realfag er kjedelig	❍	❍	❍	❍	❍
Jeg vil gjerne bli med i en vitenskapsklubb	❍	❍	❍	❍	❍
Jeg liker å se vitenskapsprogrammer på TV	❍	❍	❍	❍	❍
Jeg liker å besøke vitenskapsmuseer	❍	❍	❍	❍	❍
Jeg vil gjerne gjøre flere realfagsaktiviteter utenfor skolen	❍	❍	❍	❍	❍
Jeg liker å lese vitenskapelige blader og bøker	❍	❍	❍	❍	❍
Det er spennende å lære om nye ting som skjer innen vitenskapen	❍	❍	❍	❍	❍
Jeg vil gjerne studere mer realfag i fremtiden	❍	❍	❍	❍	❍
Jeg vil gjerne studere realfag på universitetet	❍	❍	❍	❍	❍
Jeg vil gjerne ha en jobb som omhandler realfag	❍	❍	❍	❍	❍
Jeg vil gjerne bli realfaglærer	❍	❍	❍	❍	❍
Jeg vil gjerne bli forsker	❍	❍	❍	❍	❍
Vitenskap og teknologi er viktig for samfunnet	❍	❍	❍	❍	❍
Vitenskap og teknologi gjør livene våre enklere og mer komfortable	❍	❍	❍	❍	❍
Fordelene med vitenskap er større enn skadevirkningene	❍	❍	❍	❍	❍
Vitenskap og teknologi hjelper de fattige	❍	❍	❍	❍	❍
Det er mange spennende ting som skjer innen vitenskap og teknologi	❍	❍	❍	❍	❍
Forskere har spennende jobber	❍	❍	❍	❍	❍

16. I hvor stor grad er du enig i de følgende påstandene?

	Svært uenig	Uenig	Både-og	Enig	Svært enig
Jeg liker skolen veldig godt	❍	❍	❍	❍	❍
Jeg vil anbefale denne skolen	❍	❍	❍	❍	❍
Jeg synes skolen er kjedelig	❍	❍	❍	❍	❍
Jeg føler at jeg hører hjemme på denne skolen	❍	❍	❍	❍	❍
Mesteparten av tiden skulle jeg ønske at jeg ikke var på skolen i det hele tatt	❍	❍	❍	❍	❍
Jeg kommer godt overens med de fleste av lærerne mine	❍	❍	❍	❍	❍
Jeg er vanligvis glad når jeg er på skolen	❍	❍	❍	❍	❍
Jeg jobber så hardt jeg kan på skolen	❍	❍	❍	❍	❍

E Post questionnaire (control)

Spørreskjema 2 (Kontroll) – Ungdoms interesse og holdning til naturvitenskap

Dette spørreskjemaet tar omtrent 5 minutter å gjennomføre.

Spørreskjemaet er en del av et forskningsprosjekt, hvor formålet er å undersøke hvordan spillelementer påvirker ungdoms interesse for og holdning til naturvitenskap og forskning.

Hvis du har spørsmål angående spørreskjemaet kan du ta kontakt via e-post til einaru@stud.ntnu.no eller andrend@stud.ntnu.no.

Personopplysninger

1. Brukernavn du har fått utdelt

Naturvitenskapelige aktiviteter på fritiden

Her ønsker vi å finne ut hvor mye tid du benytter på fritiden til å oppsøke naturvitenskapelig innhold.

2. Vitenskapelig eksponering utenfor skolen

	Aldri	Minst én gang i året	Minst én gang i halvåret	Minst én gang i måneden	Minst én gang i uken
Hvor ofte engasjerer du deg i vitenskapelige aktiviteter eller samhandler med vitenskapsrelatert innhold på fritiden?	❍	❍	❍	❍	❍
Hvor ofte ser du på vitenskapsrelatert innhold på internett? (F.eks. Youtube, TikTok, Instagram, etc.)	❍	❍	❍	❍	❍
Hvor ofte søker du på internett etter vitenskapelig innhold? (Vitenskapsmagasiner, nettsteder som presenterer eksperimenter osv.)	❍	❍	❍	❍	❍

3. Har du planer om å engasjere deg i flere vitenskapsrelaterte aktiviteter i fremtiden?

❍ Ja
❍ Nei

4. Har du engasjert deg i vitenskapelige aktiviteter du planla for de siste to månedene?

❍ Ja
❍ Nei

5. Har du prøvd ut vitenskapelige eksperimenter på egen hånd de siste to månedene?

❍ Ja
❍ Nei

Mestringsevne

Her ønsker vi å finne ut hvordan du oppfatter din egen mestringsevne angående naturvitenskap.

6. I hvor stor grad er du enig i de følgende påstandene?

	Svært uenig	Uenig	Både-og	Enig	Svært enig
Jeg anser meg selv som en ekspert innen naturvitenskap	❍	❍	❍	❍	❍
Jeg gjør det bra i undervisning som tar for seg naturvitenskap	❍	❍	❍	❍	❍
Jeg har mye kunnskap om vitenskap	❍	❍	❍	❍	❍
Jeg kan forklare hvorfor noe skjer og hva som skjer i naturvitenskapelige eksperimenter	❍	❍	❍	❍	❍
Jeg kan knytte kunnskapen jeg lærer fra naturvitenskap opp mot kunnskap jeg allerede har	❍	❍	❍	❍	❍
Jeg føler meg trygg på å samle og prosessere naturvitenskapelig data	❍	❍	❍	❍	❍
Jeg føler meg trygg på å bruke vitenskapelige metoder	❍	❍	❍	❍	❍
Jeg føler meg trygg på å bruke vitenskap til å løse problemer	❍	❍	❍	❍	❍

Holdning

Her ønsker vi å kartlegge din holdning til naturvitenskap og forskning.

7. I hvor stor grad er du enig i de følgende påstandene?

	Svært uenig	Uenig	Både-og	Enig	Svært enig
Det er viktig å ha kunnskap om vitenskap	❍	❍	❍	❍	❍
Det er viktig å forstå og kunne forklare hva som skjer i vitenskapelige eksperimenter	❍	❍	❍	❍	❍
Det er viktig å knytte kunnskapen jeg lærer fra naturvitenskap opp mot kunnskap jeg allerede har	❍	❍	❍	❍	❍
Det er nyttig å kunne samle og prosessere vitenskapelig data	❍	❍	❍	❍	❍
Det er viktig å kunne underbygge argumentasjon med data	❍	❍	❍	❍	❍
Det er viktig å bruke vitenskap til å løse problemer	❍	❍	❍	❍	❍

Endring i holdning og interesse

Her ønsker vi å kartlegge hvordan du opplever at din holdning og interesse for vitenskap og forskning har endret seg.

8. I hvor stor grad er du enig i de følgende påstandene?

	Svært uenig	Uenig	Både-og	Enig	Svært enig
Min interesse for naturvitenskap har økt	❍	❍	❍	❍	❍
Min forståelse for hvordan vitenskapelige metoder benyttes har økt	❍	❍	❍	❍	❍

Applikasjonen i eksperimentet

Her ønsker vi å finne ut hvordan du oppfattet applikasjonen.

9. I hvor stor grad er du enig i de følgende påstandene?

	Svært uenig	Uenig	Både-og	Enig	Svært enig
"Points of Science" var artig å bruke	❍	❍	❍	❍	❍
Jeg likte "Points of Science" veldig godt	❍	❍	❍	❍	❍
Jeg syntes "Points of Science" var ganske morsomt	❍	❍	❍	❍	❍
Jeg vil beskrive "Points of Science" som veldig interessant	❍	❍	❍	❍	❍
Mens jeg brukte "Points of Science", tenkte jeg på hvor mye jeg likte det	❍	❍	❍	❍	❍

F Post questionnaire (experimental)

Spørreskjema 2 (Eksperiment) – Ungdoms interesse og holdning til naturvitenskap

Dette spørreskjemaet tar omtrent 5 minutter å gjennomføre.

Spørreskjemaet er en del av et forskningsprosjekt, hvor formålet er å undersøke hvordan spillelementer påvirker ungdoms interesse for og holdning til naturvitenskap og forskning.

Hvis du har spørsmål angående spørreskjemaet kan du ta kontakt via e-post til einaru@stud.ntnu.no eller andrend@stud.ntnu.no.

Personopplysninger

1. Brukernavn du har fått utdelt

Naturvitenskapelige aktiviteter på fritiden

Her ønsker vi å finne ut hvor mye tid du benytter på fritiden til å oppsøke naturvitenskapelig innhold.

2. Vitenskapelig eksponering utenfor skolen

	Aldri	Minst én gang i året	Minst én gang i halvåret	Minst én gang i måneden	Minst én gang i uken
Hvor ofte engasjerer du deg i vitenskapelige aktiviteter eller samhandler med vitenskapsrelatert innhold på fritiden?	❍	❍	❍	❍	❍
Hvor ofte ser du på vitenskapsrelatert innhold på internett? (F.eks. Youtube, TikTok, Instagram, etc.)	❍	❍	❍	❍	❍
Hvor ofte søker du på internett etter vitenskapelig innhold? (Vitenskapsmagasiner, nettsteder som presenterer eksperimenter osv.)	❍	❍	❍	❍	❍

3. Har du planer om å engasjere deg i flere vitenskapsrelaterte aktiviteter i fremtiden?

❍ Ja
❍ Nei

4. Har du engasjert deg i vitenskapelige aktiviteter du planla for de siste to månedene?

❍ Ja
❍ Nei

5. Har du prøvd ut vitenskapelige eksperimenter på egen hånd de siste to månedene?

❍ Ja
❍ Nei

Mestringsevne

Her ønsker vi å finne ut hvordan du oppfatter din egen mestringsevne angående naturvitenskap.

6. I hvor stor grad er du enig i de følgende påstandene?

	Svært uenig	Uenig	Både-og	Enig	Svært enig
Jeg anser meg selv som en ekspert innen naturvitenskap	❍	❍	❍	❍	❍
Jeg gjør det bra i undervisning som tar for seg naturvitenskap	❍	❍	❍	❍	❍
Jeg har mye kunnskap om vitenskap	❍	❍	❍	❍	❍
Jeg kan forklare hvorfor noe skjer og hva som skjer i naturvitenskapelige eksperimenter	❍	❍	❍	❍	❍
Jeg kan knytte kunnskapen jeg lærer fra naturvitenskap opp mot kunnskap jeg allerede har	❍	❍	❍	❍	❍
Jeg føler meg trygg på å samle og prosessere naturvitenskapelig data	❍	❍	❍	❍	❍
Jeg føler meg trygg på å bruke vitenskapelige metoder	❍	❍	❍	❍	❍
Jeg føler meg trygg på å bruke vitenskap til å løse problemer	❍	❍	❍	❍	❍

Holdning

Her ønsker vi å kartlegge din holdning til naturvitenskap og forskning.

7. I hvor stor grad er du enig i de følgende påstandene?

	Svært uenig	Uenig	Både-og	Enig	Svært enig
Det er viktig å ha kunnskap om vitenskap	❍	❍	❍	❍	❍
Det er viktig å forstå og kunne forklare hva som skjer i vitenskapelige eksperimenter	❍	❍	❍	❍	❍
Det er viktig å knytte kunnskapen jeg lærer fra naturvitenskap opp mot kunnskap jeg allerede har	❍	❍	❍	❍	❍
Det er nyttig å kunne samle og prosessere vitenskapelig data	❍	❍	❍	❍	❍
Det er viktig å kunne underbygge argumentasjon med data	❍	❍	❍	❍	❍
Det er viktig å bruke vitenskap til å løse problemer	❍	❍	❍	❍	❍

Endring i holdning og interesse

Her ønsker vi å kartlegge hvordan du opplever at din holdning og interesse for vitenskap og forskning har endret seg.

8. I hvor stor grad er du enig i de følgende påstandene?

	Svært uenig	Uenig	Både-og	Enig	Svært enig
Min interesse for naturvitenskap har økt	❍	❍	❍	❍	❍
Min forståelse for hvordan vitenskapelige metoder benyttes har økt	❍	❍	❍	❍	❍

Applikasjonen i eksperimentet

Her ønsker vi å finne ut hvordan du oppfattet applikasjonen og hvordan de ulike spillelementene som ble benyttet har påvirket deg.

9. I hvor stor grad er du enig i de følgende påstandene?

	Svært uenig	Uenig	Både-og	Enig	Svært enig
"Points of Science" var artig å bruke	❍	❍	❍	❍	❍
Jeg likte "Points of Science" veldig godt	❍	❍	❍	❍	❍
Jeg syntes "Points of Science" var ganske morsomt	❍	❍	❍	❍	❍
Jeg vil beskrive "Points of Science" som veldig interessant	❍	❍	❍	❍	❍
Mens jeg brukte "Points of Science", tenkte jeg på hvor mye jeg likte det	❍	❍	❍	❍	❍

10. I hvor stor grad er du enig i de følgende påstandene?

	Svært uenig	Uenig	Både-og	Enig	Svært enig
Prestasjoner var artig å gjøre	❍	❍	❍	❍	❍
Jeg likte prestasjoner veldig godt	❍	❍	❍	❍	❍
Jeg syntes prestasjonene var ganske morsomt	❍	❍	❍	❍	❍
Jeg vil beskrive prestasjoner som veldig interessant	❍	❍	❍	❍	❍
Mens jeg brukte prestasjoner, tenkte jeg på hvor mye jeg likte det	❍	❍	❍	❍	❍

11. I hvor stor grad er du enig i de følgende påstandene?

	Svært uenig	Uenig	Både-og	Enig	Svært enig
Ledertavle var artig å bruke	❍	❍	❍	❍	❍
Jeg likte ledertavle veldig godt	❍	❍	❍	❍	❍
Jeg syntes ledertavle var ganske morsomt	❍	❍	❍	❍	❍
Jeg vil beskrive ledertavle som veldig interessant	❍	❍	❍	❍	❍
Mens jeg progresserte ledertavlen, tenkte jeg på hvor mye jeg likte det	❍	❍	❍	❍	❍

12. I hvor stor grad er du enig i de følgende påstandene?

	Svært uenig	Uenig	Både-og	Enig	Svært enig
Poeng var artig å få	❍	❍	❍	❍	❍
Jeg likte å få poeng veldig godt	❍	❍	❍	❍	❍
Jeg syntes å få poeng var ganske morsomt	❍	❍	❍	❍	❍
Jeg vil beskrive å få poeng som veldig interessant	❍	❍	❍	❍	❍
Mens jeg fikk poeng, tenkte jeg på hvor mye jeg likte det	❍	❍	❍	❍	❍

13. I hvor stor grad er du enig i de følgende påstandene?

	Svært uenig	Uenig	Både-og	Enig	Svært enig
Progresjon var artig å oppnå	❍	❍	❍	❍	❍
Jeg likte å oppnå progresjon veldig godt	❍	❍	❍	❍	❍
Jeg syntes å oppnå progresjon var ganske morsomt	❍	❍	❍	❍	❍
Jeg vil beskrive å oppnå progresjon som veldig interessant	❍	❍	❍	❍	❍
Mens jeg oppnådde progresjon, tenkte jeg på hvor mye jeg likte det	❍	❍	❍	❍	❍

G Response options and weights for science capital

Table G.1: Response options and weighting of science capital items used in the pre-questionnaire.

Item	Response options and weighting
En naturvitenskapelig kvalifikasjon kan hjelpe meg med å få mange forskjellige typer jobber	-2 for svært uenig, -1 for uenig, 0 for både-og, 1 for enig, og 2 for svært enig
Når du ikke er på skolen, hvor ofte snakker du om naturfag med andre mennesker?	-2 for aldri, -1 for minst én gang i året, 0 for minst én gang i halvåret, 1 for minst én gang i måneden, og 2 for minst én gang i uken
En eller begge av mine foreldre synes vitenskap er veldig interessant	-1 for svært uenig, -0.5 for uenig, 0 for både-og, 0.5 for enig, og 1 for svært enig
En eller begge av mine foreldre har forklart meg at vitenskap er nyttig for fremtiden min	-1 for svært uenig, -0.5 for uenig, 0 for både-og, 0.5 for enig, og 1 for svært enig
Jeg vet hvordan jeg bruker vitenskapelig bevis for å argumentere	-2 for svært uenig, -1 for uenig, 0 for både-og, 1 for enig, og 2 for svært enig
Når du ikke er på skolen, hvor ofte leser du bøker eller blader om vitenskap?	-2 for aldri, -1 for minst én gang i året, 0 for minst én gang i halvåret, 1 for minst én gang i måneden, og 2 for minst én gang i uken
Når du ikke er på skolen, hvor ofte besøker du et vitenskapssenter, vitenskapsmuseum, eller planatarium?	-2 for aldri, -1 for minst én gang i året, 0 for minst én gang i halvåret, 1 for minst én gang i måneden, og 2 for minst én gang i uken

Continues on the next page...

Table G.1: Response options and weighting of science capital items (continued).

Item	Response options and weighting
Når du ikke er på skolen, hvor ofte besøker du en dyrehage eller et akvarium?	-2 for aldri, -1 for minst én gang i året, 0 for minst én gang i halvåret, 1 for minst én gang i måneden, og 2 for minst én gang i uken
Hvor ofte går du på vitenskapsklubber etter skoletid?	-2 for aldri, -1 for minst én gang i året, 0 for minst én gang i halvåret, 1 for minst én gang i måneden, og 2 for minst én gang i uken
Lærerne mine har spesifikt oppfordret meg til å fortsette med realfag etter videregående	-2 for svært uenig, -1 for uenig, 0 for både-og, 1 for enig, og 2 for svært enig
Lærerne mine har forklart meg at realfag er nyttig for fremtiden min	-2 for svært uenig, -1 for uenig, 0 for både-og, 1 for enig, og 2 for svært enig
Det er nyttig å kunne vitenskap i hverdagen	-1 for svært uenig, -0.5 for uenig, 0 for både-og, 0.5 for enig, og 1 for svært enig
Hvem snakker du med om vitenskap?	0.5 for foreldre eller foresatte, 0.5 for slektninger, 0.5 for venner, 0.5 for søsken, 0.5 for direkte med forskere, 0.5 for lærere, og 0 for ingen
Kjenner du noen som jobber med naturvitenskap?	2 for foreldre eller foresatte, 1 for søsken, 1 for slektninger, og 1 for andre

Digernes and Uvsløkk

Points of Science

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