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DiaLudus

Developing a Gamified Mobile App for Pediatric Diabetes Education

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To my Mother,

and all those affected by this disease.

“I wish it need not have happened in my time,” said Frodo. “So do I,” said Gandalf, “and so do all who live to see such times. But that is not for them to decide. All we have to decide is what to do with the time that is given us.”

–J.R.R. Tolkien

Abstract

Type 1 diabetes is a chronic disease that causes significant challenges for the patient and their parents, affecting them physically and mentally. Approximately 450 children are diagnosed with type 1 diabetes in Norway yearly, necessitating lifelong self-management of their blood glucose levels. Early knowledge acquisition is crucial to improving the patient's prognosis and self-management skills. This project aims to explore the potential of an educational gamified mobile application as a valuable tool for increasing knowledge in patients early on in their diagnosis.

To gather the information necessary to design this application, we performed a systematic literature review, an interview with a medical doctor, and a discussion with a designer who is also the parent of a child with type 1 diabetes. This information was then used to create model mock-ups, which were used to create the proof-of-concept prototype: a cross-platform mobile application consisting of multiple mini-games aimed to educate children on type 1 diabetes while increasing motivation through rewards. The app was developed using the Unity game engine, along with iterative development and internal testing throughout the development stage by fellow students and members of the author's research group.

Assessment of medical accuracy in the app was performed by two medical doctors, knowledge transfer assessment was performed by students with self-reported low understanding of diabetes, and quantitative usability testing was performed by children aged 9-12 with type 1 diabetes. While the evaluation showed potential areas of improvement, it also showed that the application prototype is medically accurate, entertaining, and effective at teaching the knowledge it contains.

We have created an educational gamified mobile application designed to educate newly diagnosed children with type 1 diabetes in an exciting and entertaining manner. Evaluation of the prototype shows great promise for using gamified educational applications as a knowledge-increasing tool in treating pediatric diabetes patients.

Acknowledgements

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To my other supervisors, Gunnar Hartvigsen, André Henriksen, Ayan Chatterjee, and Antonio Martinez, for providing helpful advice, information, and feedback in every supervision meeting. Your amassed knowledge and insight proved invaluable, especially in the discussions on differing opinions.

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To my mom and dad, Cathrine and Trond Brattland, for the constant support throughout my life and a great upbringing. I have gotten where I am today thanks to standing on your shoulders. You have taught me so much that I am grateful for, and I hope to pass on that knowledge someday.

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1 Introduction

1.1 Background

Diabetes is, according to the Centers for Disease Control and Prevention (CDC) [1], a chronic condition that affects how your body metabolizes carbohydrates. Most of the food we consume is broken down into glucose and then released into the bloodstream, where it can circulate through the body and cells can use it for energy. When the level of glucose in your bloodstream, referred to as blood glucose level (BGL), increases, your body will send signals to the pancreas to produce a hormone called insulin. Insulin is then used by the cells to use glucose for energy. Patients with diabetes can not produce enough insulin or have grown insensitive to it. These conditions lead to dangerously high levels of glucose in the bloodstream, which has serious health consequences.

1.1.1 Type 1 Diabetes in Children

Type 1 diabetes is not a lifestyle disease; its cause is still largely unknown. An autoimmune reaction is believed to destroy the pancreas's cells responsible for insulin production.

A recent study conducted by an international research group [2] estimated that there were about 8.4 million patients with type 1 diabetes in 2021, although the number could be as high as 8.8 million. 1.5 million of these patients were under the age of 20. This prevalence of cases has been increasing, and they estimate

that the number could be as high as 13.5-17.4 million by 2040, an increase of 60-107%.

Type 1 diabetes inflicts a tremendous burden on those diagnosed, especially among patients diagnosed in their youth. This patient group is at a higher risk of developing mental health issues, such as depression, anxiety, and diabetes distress [3]. Diabetes is also a major cause of blindness, kidney failure, stroke, lower limb amputations, and heart attacks.

Type 1 diabetes is a chronic disease, meaning that children diagnosed with type 1 diabetes must grapple with the fact that they will be managing it for the rest of their lives. They must quickly amass vast knowledge about their condition, including physiology, nutrition, and self-management techniques. Every day will consist of constantly ensuring that their blood glucose levels are within an acceptable range, managing it through insulin and carbohydrate intake. Every meal must be calculated in detail, and they can never go somewhere without their equipment. Type 1 diabetes also affects them when they are not awake. Low blood sugar at night is common, often causing cold sweats and irregular sleep. All of these factors compound the medical burden this patient group has to deal with [4].

The annual report from The Norwegian Childhood Diabetes Registry (NCDR) [5] states that approximately 450 children are diagnosed with type 1 diabetes annually in Norway. In this report, children are defined as 18 years old or younger. The actual number was 467 in 2020 and 441 in 2021. This is twice as many as what was reported in 1970 [4].

While type 1 diabetes can occur at all ages, it is most common to develop the disease at the age of 8-12 years old [6]. It is not easy for young children to receive the news that they will have to manage a life-threatening disease for the rest of their life, and it is therefore essential that they receive all the aid they can get, both through technological tools and proper education in how to manage their disease.

Diabetes also imposes a tremendous economic burden on society. Solli et al. [7] conducted a study to estimate the healthcare costs in Norway for diabetes in 2005 and found that the disease costs healthcare services approximately €535 million. This number is likely much higher in 2023, as the number of type 1 diagnoses has increased.

With this in mind, it is clear that effective use of technology is necessary to treat patients with type 1 diabetes, both today and in the future. A gamified educational application is one way to do this.

1.1.2 Context

This Master's degree project is the second part of a longer project that started in the fall of 2022. The author completed a project researching the use of technological solutions to aid children with type 1 diabetes [4]. The project was of the type 'Capstone project' and will henceforth be referred to as such.

That project concluded that mobile applications are an effective tool to assist in the treatment of type 1 diabetes in children. It also concluded that the mobile application must be designed based on the age of the patient group it is targeting, distinguishing between young children (6-12 and younger) and the older group (12-18 years old).

For the older group, it was determined that the biggest obstacle was the motivation for self-management. Any mobile application targeted at them should increase motivation and ensure they self-manage their blood glucose levels. This is especially tricky in this age group because teenagers already have much to deal with, and ensuring consistent long-term usage was deemed incredibly challenging.

For the younger group, the most significant obstacle was their low knowledge levels. Parents usually have to take responsibility initially as they understand the condition better than the patient. Increasing the patient group's knowledge of type 1 diabetes and how to self-manage was therefore deemed highly important. One way that was determined to be efficient for this was through the use of educational games [4].

1.2 Scope and Research Problem

This project aims to research and develop a gamified, educational mobile application prototype to educate children aged 6-12 with type 1 diabetes about their disease. The intended use is for the application to part of the educational process a child goes through right after receiving their diagnosis.

In this thesis, we attempt to solve the following research problem:

> *RP: How can we design a mobile game application to educate children with type 1 diabetes on their disease?*

The research problem was divided into sub-problems.

As it is a gamified mobile application meant to educate children on type 1 diabetes, educational game design becomes essential. There are many factors in game design that must be considered as a result of the target group, especially when trying to encourage learning. Therefore, the first sub-problem is the following:

> *RP1: What factors are the most important to take into consideration when developing a gamified educational mobile application for children with type 1 diabetes?*

The application is trying to pass on medical knowledge about type 1 diabetes. It is, therefore, vital to determine what knowledge is the most important for the target group to learn. The second sub-problem is the following:

> *RP2: What knowledge should the application educate its users on?*

The Capstone project completed as preparation for this project found that it is challenging to keep children motivated to use an application over a more extended period. Therefore, it is crucial to examine tools to increase motivation and the sustained use of educational games. The third sub-problem is the following:

> *RP3: Which techniques and tools can be used to increase motivation in children to use educational games?*

1.3 Methodology

A report from the Task Force on the Core of Computer Science presents an intellectual framework for the scientific field of computer science, which was used for this project. In their report, titled 'Computing as a Discipline' [8], they present three major paradigms used for research in computer science:

1. Theory
2. Abstraction
3. Design

This project has utilized the Design paradigm, which is rooted in engineering. The paradigm utilizes four steps to construct a system or device meant to solve a given problem. The four steps are stating requirements, stating specifications, designing and implementing the system, and testing the system.

In this project, the problem we attempted to solve was how to increase knowledge of children with type 1 diabetes quickly after they receive their diagnosis. A substantive theoretical framework was established by performing a literature review, interviewing healthcare professionals, and evaluating the state-of-the-art applications available to the public. This framework was then used to determine requirements and specifications, which were used to design and implement the system. The system was then thoroughly evaluated using multiple methods to evaluate various design aspects.

1.4 Assumptions and Limitations

Children with type 1 diabetes are quite a small subset of the Norwegian population, making recruitment for testing challenging. A target group of children also have higher requirements for privacy, as they should. However, it makes the evaluation process more difficult as contacting and documenting their responses must be thoroughly planned out and receive approval before it can be performed.

The limited time frame of January to June 1st means that the project's development and evaluation phase is shorter than optimal.

1.5 Significance and Contribution

The main goal of this master's thesis was to design and provide a viable technical solution to educate children on type 1 diabetes that utilizes several smaller games referred to as 'mini-games'. The resulting mobile application is meant to educate newly diagnosed children about their condition so that they can begin early to partake in their own self-management, but the application could potentially be used to educate those of older age, a patient's friends or class-

mates, or his parents. If the application can help increase knowledge as early as possible in an entertaining way, then it is likely that it will positively affect the patient's ability to take care of themselves in the following years.

1.6 Organization

This section explains the organization of the thesis:

Chapter 2: Theoretical Framework

This chapter gives insight into type 1 diabetes in Norwegian children, what serious games are, and presents a related works search.

Chapter 3: Method

This chapter presents the methods used throughout the project, including the literature review, interviews, design, implementation and evaluation.

Chapter 4: Requirements Specification

This chapter presents the requirements specifications used for the development of the application, along with how the functional- and non-functional requirements were created.

Chapter 5: Design

The design chapter presents the overall design of the application, including game mechanisms, user interfaces, and other features.

Chapter 6: Implementation

This chapter presents specific details of the implementation process, including more detailed descriptions of how the application works under the hood.

Chapter 7: Results

The results chapter presents the results of the project, including the results of the literature review, interviews, the final application, and all evaluations performed.

Chapter 8: Discussion

The discussion chapter discusses results, findings, and various choices made throughout the project, including methodology and the final design. The chapter also discusses tasks that can be performed to potentially improve the prototype developed in this project.

Chapter 9: Conclusion

This chapter concludes the project and presents its contribution.

2

Theoretical Framework

This chapter will present the necessary theoretical framework required to understand the rest of the report.

2.1 Type 1 Diabetes

Type 1 diabetes is a chronic condition in which the patient's pancreas produces little or no insulin. It usually develops in children, teenagers, and young adults but can occur at any stage of life. Insulin is a hormone the body uses to regulate blood glucose levels (BGL). BGL is a measurement of the amount of sugar in the bloodstream. Insulin regulates this amount by helping the blood sugar enter the cells, where the cells can use glucose for energy [9].

It is not determined what causes type 1 diabetes, but the leading theory is that it is an autoimmune reaction where the beta cells in the pancreas are destroyed. These cells are responsible for the production of insulin. Specific genes increase the likelihood of developing type 1 diabetes, but those who inherit these genes from a parent often do not develop the disease [9].

2.1.1 Blood Glucose Levels

Blood glucose levels are a measurement of the amount of glucose in the bloodstream. Blood glucose levels are usually measured in either mmol/L or mg/dL.

There are various ways to test BGL. One method to gauge how blood glucose levels have been over a longer time period is through a HbA1C test, which checks glycosylated hemoglobin. The result can be used to calculate average BGL over the span of a few months. This test is performed by healthcare professionals and requires specialized equipment that is too expensive for at-home usage, and quite large. See Figure 2.1 for an example of one of these machines and how they are used to test HbA1C [10].

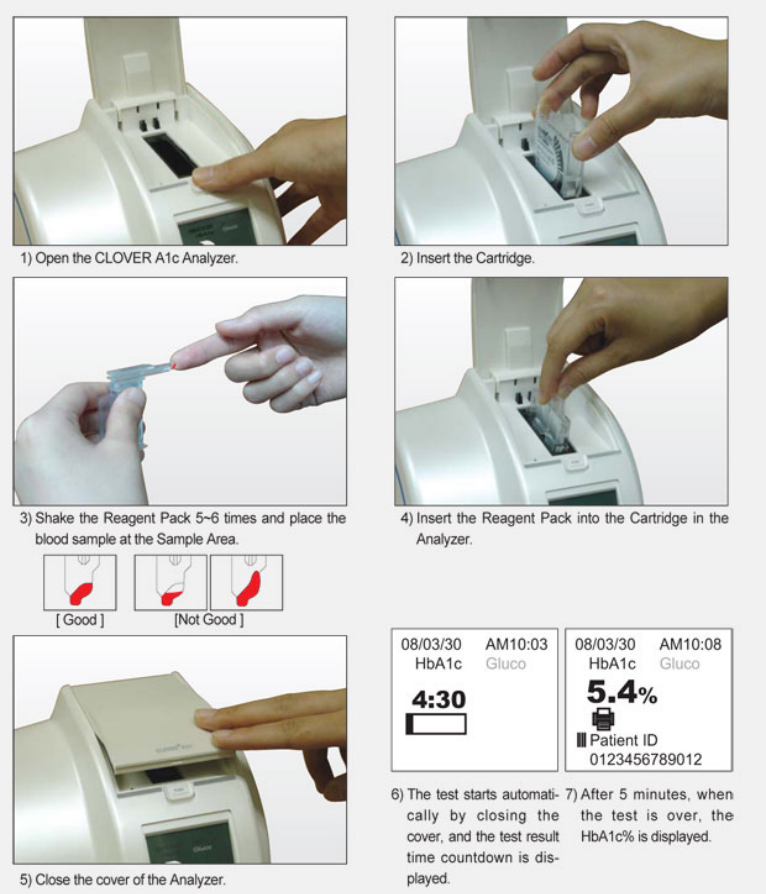

Figure 2.1: HbA1C testing machine, from Daiichi Biotech Services [10]

The more common method that patients use daily can be done anywhere with simpler technology. In this test, the patient must either draw a small quantity of blood, usually done by pricking their finger with a small needle, and a device calculates the amount of sugar in the blood [11].

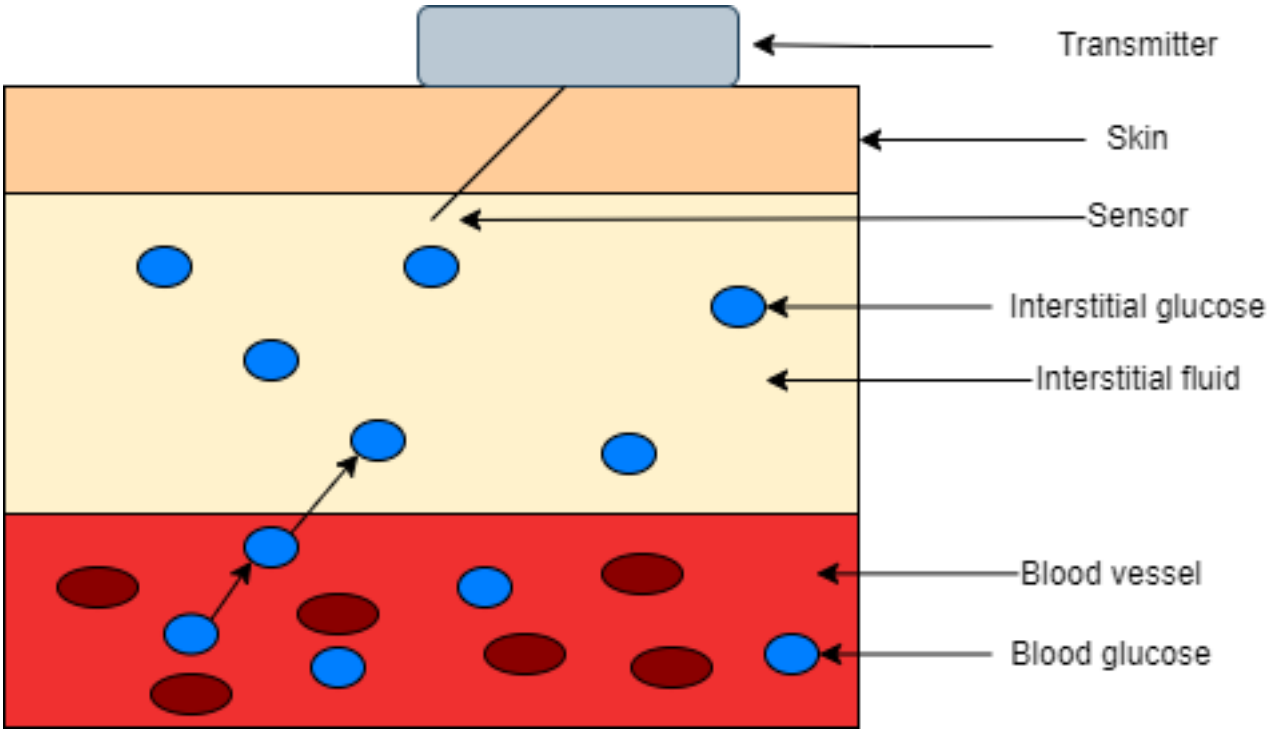

Figure 2.2: How CGMs typically work, from Capstone report [4]

Alternatively, the patient can wear a continuous glucose monitor (CGM). A CGM is a sensor placed on the skin, usually on the back of the arm or stomach. A small filament is injected into the skin, where it measures interstitial glucose levels [4]. See Figure 2.2 for a diagram of how the sensor measures blood glucose levels.

If the patient has not eaten in a few hours, their BGL will normally be considered high if it is over seven mmol/L (126 mg/dL). If the patient recently consumed carbohydrates, anything above 11 mmol/L (198 mg/dL) is considered high [12].

The symptoms of hyperglycemia are gradual but commonly include thirst, excessive urination, tiredness, weakened blurry vision, and weight loss. The most common cause of hyperglycemia is consuming excessive carbohydrates. However, other common causes that directly or indirectly can lead to hyperglycemia include feeling unwell or sick, stress, lowered activity, and missed insulin doses.

Short-term hyperglycemia is usually not a severe problem. However, over prolonged periods it can cause significant health issues, such as permanent damage

to the nerves in the patient's feet and hands, permanent damage to the eyes, and a life-threatening condition called diabetic ketoacidosis. Hyperglycemia is typically treated by administering insulin, but physical activity can also aid in lowering the BGL [12].

BGL below 3.9 mmol/L (70 mg/dL) is considered too low. Low BGL is called hypoglycemia and mainly affects diabetes patients. As a patient approaches hypoglycemia, they may experience early symptoms such as perspiration, feeling tired, dizziness or light-headedness, hunger, tingling, shaking, or trembling, and often become more easily irritated or moody. As the BGL goes lower, the symptoms can develop into weakness, blurry vision, confusion or concentration issues, slurred speech or clumsiness, feeling sleepy, seizures, or passing out. Hypoglycemia can be treated by consuming carbohydrates which will raise the BGL [13].

2.2 T1D in Norwegian Children

Out of 100 000 children in Norway, approximately 38 children aged 0-14 years are diagnosed with diabetes. In 2018 the total number of children with T1D was 2820, representing 97% of the total cases of diabetes in children.

The treatment of T1D can be divided into two categories: medicinal treatment and self-management. The medicinal treatment requires the patient to administer insulin to manage their BGL. Self-management includes regulating BGL, nutrition, and physical activity [14].

2.2.1 Nutritional Advice

Children with T1D are recommended to maintain a normal healthy diet, which entails covering the need for necessary micro- and macro-nutrients. It is also desirable to adequately regulate blood glucose levels and avoid or reduce overweight and obesity. A healthy diet prevents lifestyle diseases, especially cardiovascular and pulmonary diseases, and is an important contribution to everyday life [6].

2.2.2 Physical Activity

Children are recommended to participate in physical activity, just like other children. It is, however, important that children learn to adjust their carbohydrate intake and insulin injections based on their physical activity [14].

Physical activity can lower blood glucose levels. One way is through increased insulin sensitivity, which increases the cells' ability to utilize the available insulin to take up glucose during and after physical activity. The other way is through muscle contraction, which makes your cells able to take up glucose and use it for energy, independent of the availability of insulin [15].

It is also important to be aware that high-intensity exercise, such as weightlifting, sprints, and sports, can cause the body to excrete stress hormones such as adrenaline. Adrenaline stimulates the liver to release glucose, which in turn raises blood glucose levels [16].

2.2.3 Technology

Technology is an integral part of the self-management of type 1 diabetes, which has developed rapidly over the last decades. Technology is necessary to measure blood glucose levels and administer insulin, but the technology utilized varies greatly. The most popular technological solutions [4] can be listed as:

1. Insulin pen and finger-pricking
2. Continuous Glucose Monitor
3. Insulin pump
4. Artificial Pancreas, which combines options 2 and 3

Technological solutions 1 and 2 have already been explained in Subsection 2.1.1. An insulin pump is a device that can deliver small doses of insulin throughout the day. The pump is usually carried close to the body, or in some cases, directly against the skin. Most insulin pumps then administer the insulin through tubing connected to the body. The doses of fast-acting insulin can be administered in small doses throughout the day, and larger doses must be manually instructed before the patient eats a meal with carbohydrates.

In some cases, the insulin pump is connected to a continuous glucose monitor, and this is the basis of an artificial pancreas or a closed-loop system. In this solution, the CGM feeds the pump with blood glucose levels, and the pump calculates the optimal insulin doses to keep blood glucose levels within a healthy range [17].

All patients diagnosed with type 1 diabetes in Norway have the right to be considered for an insulin pump and CGM [18]. The only requirement is that you must be treated in a specialist health service (hospital or clinic). The doctor

or diabetes nurse can then apply for you and ask for the equipment best suited for your needs. See Table 2.1 for an overview of the available equipment in Norway based on today's temporary agreement.

Table 2.1: Overview of available equipment in Norway [18]

Ranking	Provider	Product
Contract 1 - Insulin pumps w/CGM - Closed Loop		
#1	Medtronic Norge AS	Minimed 780G
#2	Rubin Medical AS	Tandem t:slim X2 (Control IQ)
Contract 2 - Patch pump for insulin		
#1	NordicInfu Care AB	OmniPod Dash
#2	Roche Diagnostics Norge AS	Accu-Chek Solo
Contract 3 - Freestanding CGM		
#1	Abbot Norge AS	Freestyle Libre 2
#2	Abbot Norge AS	Freestyle Libre 3
#3	Medtronic Norge AS	Guardian 4
#4	NordicInfu Care AB	Dexcom G6
#5	Ascensia Diabetes Care Norway AS	Eversense E3

These gadgets are continuously becoming better and better with each iteration, and an interview with diabetes nurses in the fall of 2022 revealed that most children in Norway that are diagnosed at a young age are recommended to use an artificial pancreas or closed loop system [4].

The author tested two iterations of Abbot's Libre sensor as part of this project, testing the Libre 2 in the fall and the Libre 3 in the spring semester. See for a comparative image of what the sensors look like.

Figure 2.3: Comparison of Libre 3 (left) and Libre 2 (right) sensors, photos by Sigurd Johannes Brattland

It is worth noting that the Libre sensor has halved in size from the Libre 2 to Libre 3 model, and one can barely feel that you are wearing the CGM. The author often forgot it was there, even during strenuous exercise. Many sensors also come with accompanying mobile applications. The Libre 3 has a mobile application that continuously receives blood glucose readings from the sensor via Bluetooth and has programmed alarms if the user's BGL goes dangerously low or high. It also provides detailed logbooks of the user's BGL throughout the day. See Figure 2.4 for a screenshot of what a day of blood glucose readings looks like in this application for a person without diabetes.

Figure 2.4: Screenshot of a day's log on Libre 3 mobile application, photo by Sigurd Johannes Brattland

2.3 Serious Games

'Serious games' is the concept of using games to achieve something beyond just entertainment [19]. Serious games can be used for many purposes, such as simulator training, improving skills, and education. The latter part is commonly referred to as 'Serious Educational Games,' or just 'educational games.' Fields that use serious games include the defense industry, healthcare, education, engineering, and politics. See Figure 2.5 reprinted from Ullah et al. [19] for an overview of the relationship between games, video games, serious games, and educational games.

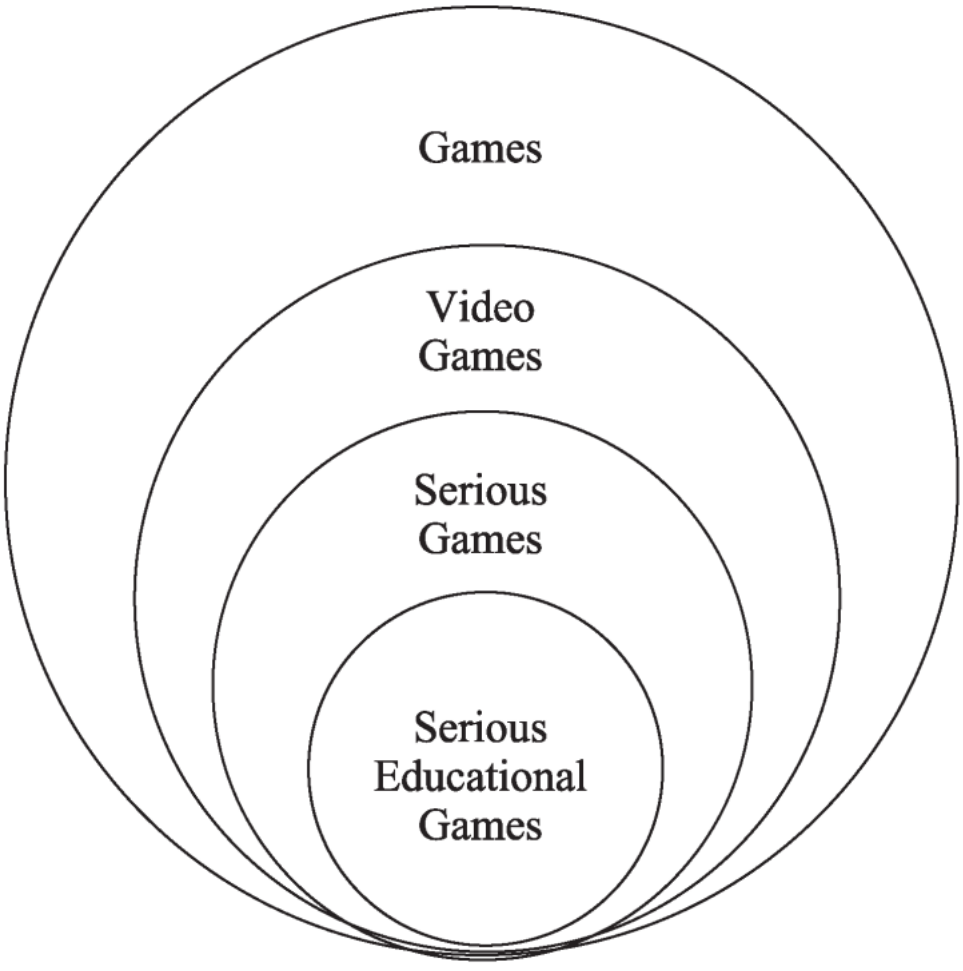

Figure 2.5: Relationship between games, video games, serious games, and educational games, from Ullah et al. [19]

The use of computer games has been proven to be especially useful in the education of children. The use of computer games to teach scientific subjects goes as far back as the 1970s. Serious educational games have been proven to increase motivation in children and enhance knowledge acquisition while promoting critical thinking, problem-solving, and encouraging collaborative effort [19].

2.4 Related Works

Existing publicly available applications that provided a similar service were reviewed to gather useful information on potential features and their effectiveness.

2.4.1 Data Sources

The following mobile application platforms were included in the search:

- Google Play [20]
- App Store [21] (via third-party service)

Access to the App Store requires an Apple product. Therefore, a third-party search service named ’fnd.io’ was used instead of the Apple-provided application. This service was created by Jeremy Mack and Ryann Mack, and conducts searches against the App Store by using the iTunes Affiliate Program. The service requires you to define what country you are in, as location affects App Store search results [22].

2.4.2 Search Methodology

The search engines of these services are more simple than those in scientific journals, so the search was kept relatively broad.

The search terms were constructed in two parts:

- The included applications had to target diabetes patients

  "Diabetes"

- The included applications had to include some sort of gamified aspect to

it.

"Game(s)"

The desire was that these two terms would lead to gamified applications targeted at diabetes patients. This led to the following search term:

```
"Diabetes games"
```

2.4.3 Exclusion Criteria and Screening

Exclusion criteria

The following criteria had to be met by the applications:

- The app must be in either English or Norwegian
- The app must be targeted at diabetes patients
- The app must contain gamified aspects

Screening

The applications went through two screenings:

1. Screening based on title and picture
2. Screening based on the description

The second stage of screening applied when it was not entirely clear in the first stage that the app did not meet the search criteria.

See Figure 2.6 for an overview of the screening process of existing applications.

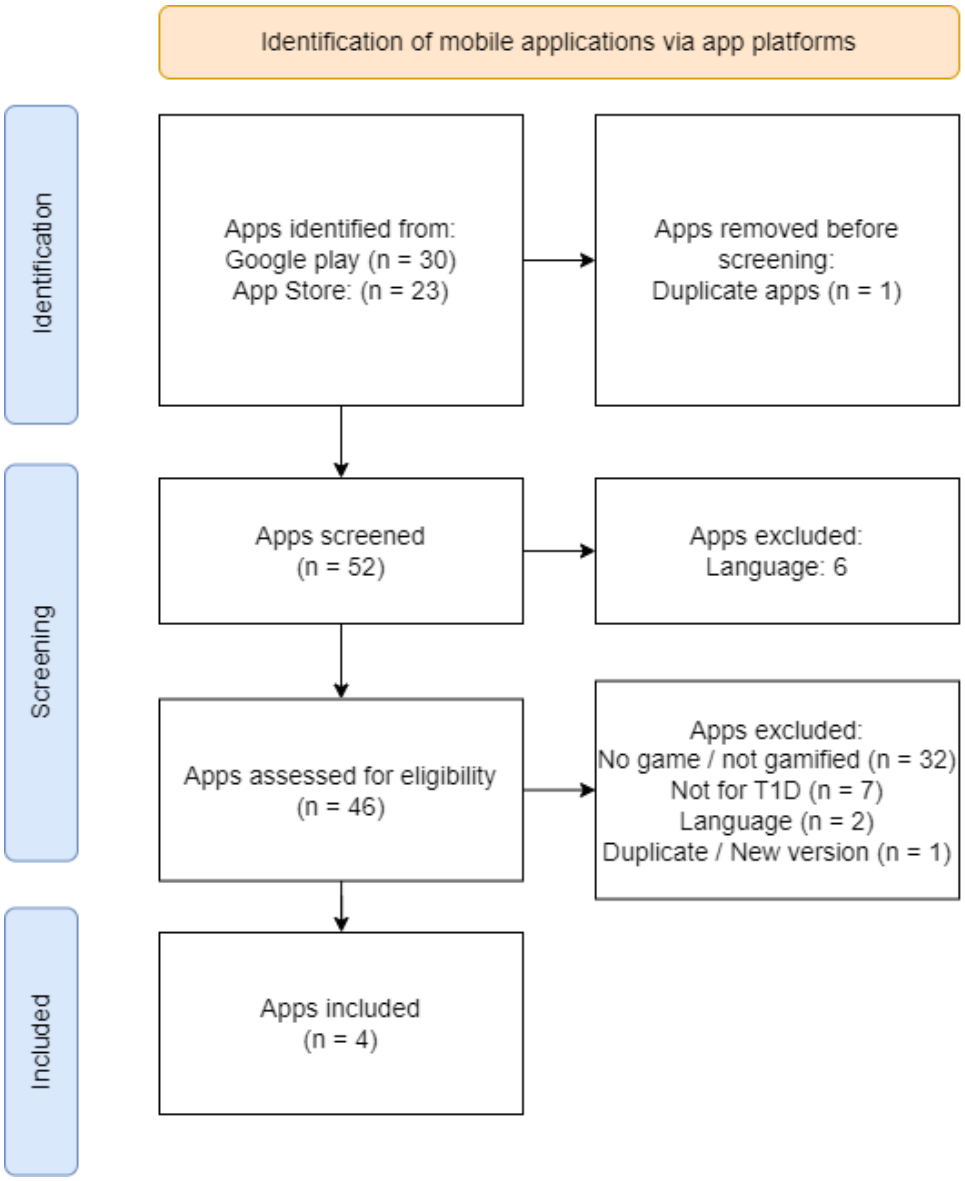

Figure 2.6: PRISMA diagram for application search

The included applications and their details can be found in Table 2.2

Table 2.2: Included existing applications

Application name	Publisher	Platform(s)
Rufus, the Bear with Diabetes [23]	Sproutel, Inc	Google Play, App Store
Gusse - Diabetes Type 1 [24]	10:30 DK ApS	Google Play, App Store
Diabetes in your body [25]	Cheryl Montgomery (App Store), iCUBE (Google Play)	Google Play, App Store
Diabetic's Diner [26]	Rx Interactive, Inc.	App Store

2.4.4 Findings

Rufus, the Bear with Diabetes

The Rufus application is a mobile application based on an existing stuffed bear used in treating children with type 1 diabetes. The application lets children gain practical experience with diabetes self-management through games. The users can feed the teddy bear, measure blood glucose levels, and administer insulin through a pen or pump. See Figure 2.7 for screenshots of the application [23].

Figure 2.7: Two screenshots of the Rufus application, from its Google Play page [23]

Gusse - Diabetes Type 1

Gusse is an application meant to introduce children newly diagnosed with type 1 diabetes, their parents, and those around them, to the hospital setting and their treatment. The application uses interactive animations to teach the user about the physiology of diabetes, self-management, a diabetic diet, school life with diabetes, and the hospital setting. See Figure 2.8 for screenshots from the application's Google Play page [24].

Figure 2.8: Two screenshots of the Gusse application, from its Google Play page [24]

Diabetes in Your Body

Diabetes in Your Body is an application developed as a partnership between the Cookeville Regional Medical Center and Tennessee Tech University. The application lets children explore the body and how diabetes affects it through advanced, detailed graphics and accurate medical information. See Figure 2.9 for two screenshots from the application's App Store page [25].

Figure 2.9: Two screenshots of the Diabetes in Your Body application, from its App Store page [25]

Diabetic's Diner

Diabetic's Diner is a gamified diabetes application by Rx Interactive. The application is designed to allow users to have fun learning about beneficial foods for people with diabetes. The primary mechanism of the game is about "good" and "bad" foods falling from the top of the screen, and then the user should catch the "good" foods. See Figure 2.10 for screenshots from the application's App Store page [26].

Figure 2.10: Two screenshots of the Diabetic's Diner application, from its App Store page [26]

2.5 Summary

In this chapter we have described type 1 diabetes and its effect on children, how children in Norway are treated by the healthcare services, and how they must self-manage their disease. We have described what serious games are and how they are an effective tool to educate children, along with presenting related commercial applications.

3

Methods

This chapter describes the methods used to design, implement, and evaluate the mobile application.

3.1 Review of the Literature

3.1.1 Data Sources

The following electronic databases were used in the literature review:

- PubMed [27]
- IEE Xplore [28]
- ACM Digital Library [29]

3.1.2 Search Methodology

Query groups were created to determine the query for the literature search:

The query was built from these five query groups:

Table 3.1: Query groups and their definition

Query Group	Definition
1. Target Group	The target group of the included studies
2. Illness	The condition the presented solution should be targeting
3. Technology	The type of technology presented in the study
4. Style	The style of the technologies included
5. Exclusion	Any subjects, categories, or other terms that should not be included in the search.

1. The target group for this project was young children, defined loosely as those 12 years old or younger. Therefore the target group was set as the following:

```
(Child* or Kid*)
```

2. The illness that we are targeting in this thesis is type 1 diabetes. Therefore, the following terms were used:

```
(Type 1 diabetes OR T1D OR T1DM OR Type 1 diabetes mellitus)
```

3. The technology we want to review in this thesis is mobile applications or games. Therefore, the following terms were included:

```
(Mobile app* OR mHealth OR Smartphone app* OR Gamified app*)
```

4. The style of technology we are reviewing is educational games. The following terms were chosen to fetch as many results as possible:

```
(Diabetes Education OR Educational games OR Serious games)
```

5. Certain terms were chosen for the exclusion group as they often lead to irrelevant results, but we also wanted to exclude any papers focusing on type 2 diabetes:

```
NOT (covid* OR corona* OR animals OR Obesity OR Type 2 diabetes)
```

From these query groups, the following query was constructed:

(("Child" or "Kid*")) AND (("Type 1 diabetes" OR "T1D" or "T1DM" OR "Type 1 diabetes mellitus") AND ("Technology" OR "Mobile app*" or "mHealth" OR "smartphone app*" OR "Gamified app*") AND ("Diabetes Education" or "Educational game*" OR "Serious game*") NOT (covid* or corona* or animals or obesity or "type 2 diabetes")*

Some adjustments to the query formatting were necessary for the various database search engines.

3.1.3 Exclusion Criteria and Screening

The following main exclusion criteria were used:

- The study had to be written in English
- The study had to have a target group aged 12 or younger
- The target group must have type 1 diabetes
- The study must include a gamified application

The results went through three screening stages:

1. Screening based on the title
2. Screening based on the abstract
3. Screening based on the full text

Stage 3 was only necessary if the first two stages did not make it evident if it should be included or not.

3.2 Interview with Healthcare workers

3.2.1 Data Protection Officer

The interview process started with consulting the university's Data Protection Officer (DPO). The e-mail contained the following main points:

- The interview will include healthcare professionals at the University Hospital of Northern Norway (UNN)
- The interview will ask them about their professional opinions regarding the education of children about type 1 diabetes
- The interview will require approval from Sikt [30] since they will be recorded for transcriptions, which are classified as personal data.

The e-mail asked for recommendations or if there were any other requirements to conduct this interview. The DPO did not have any further recommendations. See Appendix E for screenshots of the correspondence.

3.2.2 Approval From Sikt – Kunnskapssektorens tenesteleverandør

An application to Sikt [30] was sent on 14.02.2023. The application contained information regarding the following:

- What personal data was going to be managed
- The background information that was going to be managed
- Project information
- Interviewee selection
- Data collection methodology
- Interview guide
- Consent form

See Appendix A for the consent form.

The application was processed by an automated system the day after and was approved.

3.2.3 Recruitment

Recruitment was performed by contacting a diabetes nurse at UNN who had participated in an interview for the earlier capstone project [4].

An e-mail was sent to the nurse on the 16th of January explaining the premise of the thesis and asking if the team at the pediatrics outpatient department were interested in participating.

The response was positive, and on the 17th of March, the team held an internal meeting where multiple healthcare workers declared interest in participating.

3.2.4 Interview methodology

The interview was a semi-structured interview. Magaldi et al. [31] define a semi-structured interview as:

> "(...) an exploratory interview used most often in the social sciences for qualitative research purposes or to gather clinical data. While it generally follows a guide or protocol that is devised prior to the interview and is focused on a core topic to provide a general structure, the semi-structured interview also allows for discovery, with space to follow topical trajectories as the conversation unfolds."

Following this definition, an interview guide was designed to focus on the core topic of necessary knowledge for newly diagnosed children with type 1 diabetes. The interview guide consisted of key questions and potential follow-up questions. See Table 3.2 for the table of questions used as the interview guide.

The interviews were held in Norwegian because it was the native language of the healthcare personnel and author, resulting in a more natural interview experience. Therefore, the questions specified in the interview guide were translated into Norwegian during the interview, and the answers and discussion were transcribed and translated into English as accurately as possible.

3.3 Video-call With Designer

A video call was held with the parent of a child with type 1 diabetes. The parent was an associate of the author's supervisor and volunteered to join an informal chat about the project. The conversation was held in a Teams call. The author presented the project, then discussed it, and received advice from the parent, who also happens to be a system designer. The supervisor was also present.

Table 3.2: Interview guide for healthcare workers regarding necessary knowledge of T1D

Question	Elaboration Questions
What is the most important information that the patient needs to learn early?	How would you prioritize the information, if possible?
What do they need to know about nutrition?	What should they learn about carbohydrates? Are there any special things you think need to be considered?
What do they need to know about physical activity?	Are there any unexpected effects from physical activity that should be taught?
What do they need to know about blood glucose management?	What equipment do they receive education on?
Is there other information that you believe is critical for children with T1D to learn?	
What information do you see produces the best long-term results for quality of life and management of the disease?	
What are the people around the patient taught?	How are classmates or friends informed about their condition?

3.4 Conceptual Model Mock-ups

Conceptual model mock-ups, in the context of system development, are used to evaluate a design at an early stage of the design process. The mock-ups are simple presentations of key features that the design will include, such as illustrations. These can be both digital and written on paper, often referred to as ’paper prototypes’ [32].

The purpose of performing such an early evaluation process is to understand whether a feature is worth developing. For example, a conceptual model mock-up might reveal that a user interface is too complex for the product’s target group, prompting a swift change in the design before any time has been wasted implementing a faulty one [32].

Early mock-ups are also useful to perform before starting implementation, as the design process itself is already performed [32]. This ensures that the person implementing the design does not have to make design choices on the go, which can quickly become biased by what is more convenient for them or what they are familiar with.

3.5 Materials

The following materials were used to create the application presented in this project:

3.5.1 Unity Game Engine

The application was created using the Unity game engine (version 2021.3.16f1) [33]. Unity is a cross-platform game engine by Unity Technologies, providing a graphical user interface for developing games along with C# code for scripting. Unity is a leading game engine, and Unity Technologies claims that 50% of all games are made in their engine, and over 5 billion Unity-based apps have been downloaded. One example is the viral mobile game Subway Surfers [34].

Unity was chosen due to its popularity, which ensures detailed documentation and an active community that provides guides and help to common issues. The cross-platform capability ensures that almost anyone can use the application, no matter what phone they have. Unity also has good performance and enables easy tweaking and debugging. The Unity engine is also free to use for students while providing professional quality tools.

The Unity Editor provides build support for PC and Android applications, meaning no external software had to be used to build and test the solution. A phone can be connected to the PC through a USB cable, and the solution installation file in APK format can be directly installed onto it.

3.5.2 Unity Asset Store

The Unity Asset Store [35] is a platform containing both free and commercial assets for the Unity game engine. Unity Technologies creates some of the assets, but the platform is driven by the fact that freelance developers can release their own assets and earn money from sales.

The main character, Ludus, is such a free asset. The asset is called "The Legend of Slim" [36] and is a free asset containing multiple sprites of the slime.

Some of the food sprites were used from an asset titled "150+ Food Icon Pack" [37].

3.5.3 Interactive Developer Environment

All code for the application was written in the interactive developer environment (IDE) Microsoft Visual Studio Community 2022 (64-bit), version 17.5.3 [38]. Visual Studio was chosen as the IDE due to its compatibility with Unity and its extensive debugging, linting, and auto-completion tools.

3.5.4 Mobile Phone

A Samsung Galaxy S20 provided by the research group was used to test the application during development. The phone runs Android version 12.

3.5.5 Alternatives

Other game engines were considered for the solution but were not chosen due to their drawbacks.

One alternative was the Unreal game engine [39]. It also provides cross-platform compatibility, a visual interface, and solid performance. However, the Unreal engine was deemed to have too high system requirements, a steep learning curve due to its complexity, and limited flexibility that could hamper development.

Starling [40] was briefly considered because it is a lightweight, simple, and free game engine. Angry Birds was created using Starling. However, the game engine utilizes ActionScript, which would involve learning a new language that could hamper development. It is also less popular than both Unity and Unreal.

3.6 Development techniques

3.6.1 Modular Design

Modular design in software development refers to designing a logical structure of reusable, self-contained parts whenever possible. Functionality is divided into separate components meant to handle limited functionality that does not depend on complicated relationships with other components. This ensures that change to one part of the system does not affect other parts of the system and makes it easier to expand the system by adding new components and features [41].

3.6.2 Self-documenting Code

Self-documented code, in the context of software development, is a method where the engineers follow naming and structured programming conventions that enable others to understand the system without any prior knowledge. Self-documented code should be easy to read and understand, require minimum effort to maintain, and reduce the need for others to consult secondary documentation such as manuals or source code comments [42]. Some of the conventions designed to ensure these are:

- Human-readable naming of variables, functions, files, and methods
- Clear and clean code structure for human reading
- Uniform naming conventions and consistency

3.6.3 Iterative Development

Iterative development is a popular software development method that involves breaking a more extensive problem into smaller, more manageable problems. Working with less extensive tasks also allows for continuous feedback and adjustments during development, which lowers the risk when uncertainties are

in place [43].

Each mini-game was implemented separately, which allowed the author to show it to others to receive feedback and make adjustments throughout development.

3.6.4 Internal Testing

The author tested the solution constantly throughout development to ensure quality, discover bugs, improve usability, and balance game difficulty. Participants included the students with whom the author shared an office, other students, supervisors, and family. The author's family includes one parent with type 1 diabetes and one medical doctor.

3.6.5 Stand-up meetings

The students working under the Health Informatics % Technology (HIT) research group at UiT Arctic University of Norway (UiT) performed daily stand-up meetings towards the end of the master's project. Stand-up meetings are a standard method in software development for team projects, where the team holds short, daily meetings to update each other on everyone's status and solve potential hurdles that are holding them back [44]. The students did not work on the same project as a team, but holding the meetings allowed students to more easily determine what they were trying to achieve that day while holding each other accountable.

3.6.6 Image generation

Imagine generation by machine learning models was used to create some of the graphics in the solution application. Generating the images removes the hassle of finding copyright-free images, and provides high-quality images. DALL-E 2 by Open AI [45] was used in this project.

3.7 Usability Testing

Deborah J. Mayhew [32] defines usability as a measurable characteristic of a user interface, with emphasis on:

- how easy it is for novice users to *learn* how to use the UI.

- how easy it is for experienced users to use it long-term.

Mayhew also explains that several factors must be considered when developing a user interface to ensure a high degree of usability. These include:

- Perceptual and cognitive capabilities of users.
- Unique characteristics of the target group.
- Unique characteristics of the target group's needs.
- Unique capabilities and constraints for the software, hardware, and platform chosen for the product.

3.7.1 System Usability Scale

The System Usability Scale (SUS) is a global standard for quick and cost-efficient quantitative evaluation of a system's usability [46].

SUS uses a Likert scale, meaning that it presents a statement, and then the user responds on a scale of whether they agree or disagree. SUS utilizes ten such statements and allows the user to respond on a scale from 1-5, where one represents 'strongly disagree' and five means 'strongly agree' [46]. See Appendix C for the form used.

The SUS scale was used after the respondents had used the app, but without any debriefing or discussion between the respondent and author, as is recommended by the author of SUS [46]. The respondents were asked to provide their immediate response to the questions, answer all questions, and if they felt unsure or could not respond, then mark the center value.

The result of a SUS form is a single number representing a composite evaluation of the over-arching usability of the solution. SUS also notes that individual question answers are not meaningful on their own [46].

Odd numbers in the questionnaire are positively weighted, and even numbers are negatively weighted. Each question results in a score contribution ranging from 0-4. Odd-numbered questions are calculated based on the answer minus one (e.g., a five on question 1 leads to 5 - 1 = 4.) Even-numbered question contributions are calculated by subtracting the answer value from 5. (e.g., the answer five on question 2 to leads to 5 - 5 = 0). All values are then summed and multiplied by 2.5 to obtain the final SUS score from 0-100 [46].

3.7.2 Approval From Sikt

As the target group for the evaluation was children with type 1 diabetes, it was deemed necessary to apply to Sikt for approval. The DPO confirmed this in Figure E.2 in Appendix E. An application was sent to Sikt on the 3rd of April.

3.7.3 Recruitment

Various methods were used to recruit users to evaluate the system's usability.

The medical doctor mentioned in Section 3.2 agreed to attempt recruitment among patients that fit the target group.

Two Facebook groups on the topic of type 1 diabetes were contacted. The author contacted the group administrators to ask permission before posting about recruitment for the evaluation. Both groups were Norwegian, as the target group is Norwegian, and the application uses Norwegian text.

3.8 Knowledge Transfer

It was desirable to measure if the application increased knowledge of type 1 diabetes in users. The target group of newly diagnosed children with type 1 diabetes was deemed challenging to get hold of. Most diabetes patients also have a pretty good understanding of type 1 diabetes, so they were not considered valid for this evaluation form. The evaluation was instead performed by fellow students at UiT with little to no knowledge of type 1 diabetes. The evaluation process consisted of three steps:

1. Answer a small quiz about type 1 diabetes.
2. Test all of the games in the application.
3. Answer the same quiz again.

The result of each quiz was a numeric score, where the values before and after testing the application can be compared.

No identifiable, personal, or sensitive information was gathered, and it was unnecessary to apply to Sikt. The participants agreed verbally to participate

and were given a random code of three letters to provide in the quiz so that the two answers could be paired in the analysis of the results. See Appendix B for the questionnaire used.

3.9 Presentation With Research Group

The application was presented during a meeting with the Health Informatics & Technology (HIT) research group at the university to get expert feedback. The audience consisted of professors, researchers, and fellow students. The author presented the application by projecting the application from a phone onto a large screen and demonstrated the various features while explaining them. The audience could ask questions and provide feedback during the demonstration. The meeting was held on the 12th of May. See Figure 3.1 for a photo taken at the presentation.

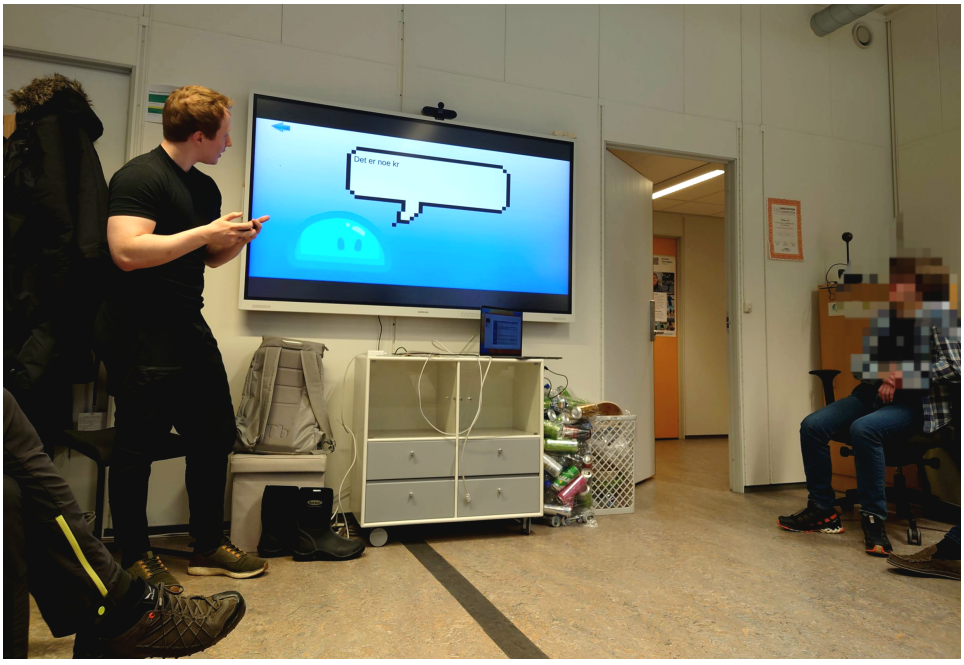

Figure 3.1: Author presenting the application to the HIT research group at UiT, photo by Eirik Årsand

3.10 Testing by Medical Doctors

Two medical doctors tested the application. The motivation was to ensure that the information presented in the application was correct and whether they thought it could be helpful for patients. One medical doctor was the same doctor who participated in the interview presented in Section 3.2. The other medical doctor is a family member.

Testing consisted of letting them install the application and test the different modules. They could then provide feedback through conversation, either in person or on a call.

3.11 Data Collected

All data collected from participants of this project was deleted on the 1st of June, as informed in the consent forms.

3.12 Summary

This chapter has presented the methods used in this project. A systematic literature review was performed to gain insight into what medical knowledge was necessary for children to learn, how to motivate them to utilize the system, and other factors that were important to consider. A medical doctor was interviewed to gain an expert opinion on what medical information the target group needs to learn. Sikt and the university DPO approved the interview. The author had a video call with a designer who is also a parent of a child with diabetes to discuss various design aspects and considerations of a system like this. Conceptual model mock-ups were used to design the system. Unity was chosen as the game engine for the project, and the chapter describes why it was chosen and possible alternatives. This chapter has also described the development techniques used to implement the system. Finally, the chapter describes how the system was evaluated on the factors of usability, knowledge transfer, and medical information accuracy.

4

Requirements Specification

This chapter describes the requirement specification for the mobile application, covering both functional- and non-functional requirements.

4.1 Source of Requirements

The requirements for this project were based on the results of the completed capstone project [4], related works, the literature review, interview, and accumulated knowledge about system development.

The specified requirements will be functional- and non-functional based on the Volere Requirements Specification Template [47].

Functional requirements describe the necessary functionality of the application, i.e., what does the application need to do. Non-functional requirements are properties that the application must have, such as its usability, performance, privacy, and security [47].

4.2 Personas, Scenarios & User Stories

Atlassian [48], a well-known Australian software company developing products for software development, defines a user story as:

> "A user story is an informal, general explanation of a software feature written from the perspective of the end user. Its purpose is to articulate how a software feature will provide value to the customer." [49]

User stories are useful for creating system requirements, as they prioritize the user over the system and the developer. Therefore, they emphasize the need of the user and how the application positively affects the user's life. They are also written in non-technical language so anyone can easily read them [49]. They are usually structured in the following format:

```
As a [persona], I [want something], [so that]
```

Atlassian [49] also specifies that a user story should provide the development team with the following information about the application they're working on:

1. Why they are developing it.
2. What they are developing.
3. What value it provides to the user.

4.2.1 Personas

Personas are an essential part of user stories. Personas are characterizations that encapsulate the most important traits of the target group for your system. The intention of using personas is to help provide a different perspective on your system and how it can benefit users. Personas are usually assigned descriptive and creative names, a caricature, and a description of their traits. Their design will be based on the information provided by the Interaction Design Foundation [50].

Persona 1: Newly-Diagnosed David

Figure 4.1: Persona 1: Newly Diagnosed David, AI-generated art using DALL-E 2 [45]

Age: 9 years old
Work: Primary school student
Family: Parents and one older sister
Location: Tromsø, Norway

Interests: David loves playing video games on his PlayStation and tablet, enjoys playing outside with his friends, and occasionally goes hiking with his family.

Technology usage: David has access to a video game console, a mobile phone, and the family's tablet.

A Typical Day: David gets up at 07:30 and eats breakfast at home before heading to school at 08:10. School times vary, but lunch is at 11:15, and he is usually home by 15:00. David plays games until his parents come home to make dinner. In the evening, he is either outside playing with friends or playing more video games at home. He then eats one meal before going to bed.

Future Goals: David wants to become a fireman when he grows up.

4.2.2 Scenarios

Scenarios are a popular aspect of user-centered design methodology. A scenario is a story about how a system is used to accomplish a task and consists of multiple steps. Scenarios are much simpler than user stories and attempt to provide a larger picture of how a system can aid a user [51].

Scenario 1: Newly-Diagnosed David is diagnosed with type 1 diabetes

David has been feeling ill lately, peeing often, losing weight, lightheartedness, dizziness, and excessive thirst. His parents take him to his general practitioner, who quickly suspects diabetes as an option, and he is soon diagnosed with type 1 diabetes at the hospital. This means that David and his parents must undergo an educational program to ensure they have the necessary knowledge to manage his new condition. There is much information for young David to learn, which is quite overwhelming. He needs to understand what is happening in his body and manage his blood glucose levels. The sooner he can gain a solid understanding of it, the better his self-management is projected to be. A mobile application filled with fun, enticing mini-games is the perfect way to add some learning in the evening after a long day visiting the hospital.

Scenario 2: Newly-Diagnosed David Goes Back to School

David returns to school sometime after being diagnosed with type 1 diabetes. Most of his classmates are curious about his absence and have many questions. With his new condition and risk of hypoglycemia, the teachers and students must have some understanding of his condition so that they can know what to do in case something happens to him. David lets them try out the game on his phone, passing the phone around so every student in the class has an increased understanding of his disease.

4.2.3 User Stories

From the persona and scenarios, the following user stories were developed:

US1: As a user, I want to play a fun educational game so that I can learn something about having type 1 diabetes.

US2: As a user, I want to play a fun game that teaches me what type 1 diabetes is, so that I understand the mechanics of my disease.

US2: As a user, I want to play a fun educational game that teaches me about blood glucose level management so that I can better regulate it.

US3: As a user, I want to learn about how physical activity affects my blood glucose levels so that I can better regulate it.

US4: As a user, I want to earn rewards for playing the game so that I'm more motivated.

4.3 Functional Requirements

Based on scenario 1, the main requirement is defined as:

Create a gamified mobile application that can educate newly diagnosed children with type 1 diabetes.

The requirements are made using the Volere Requirements Specification Template (edition 18/2016) adapted by the company ReqView [47]. The template has been further adapted to fit the purpose and constraints of this master's project.

Each requirement will include the following attributes:

- **Id:** A unique identifier for the requirement.
- **Description:** The intent of the requirement.
- **Rationale:** An explanation of why the requirement is important and how it contributes to the purpose of the mobile application.

- **Originator:** The source that suggested the requirement.
- **Criterion:** A goal the solution has to meet.
- **Priority:** How important the requirement's implementation is to the purpose of the project. Scored on a range from 1-5 where 5 is the highest priority.

The requirements are based on the user stories and scenarios presented above and influenced by the parties mentioned above. The medical doctor interviewed for the project will be referred to as 'MD' in requirements. The designer and father of a type 1 diabetes patient will be referred to as 'Designer'.

Table 4.1: List of requirements for the application prototype

Id	Description	Rationale	Originat	Criterion	Priority
REQ1	The mobile application should start	The user can't utilise it if it won't start	Author	App starts when pressed	5
REQ2	The user should be able to choose which mini-game to play	It's frustrating to not be able to do what you want and some users might want to play one game but not the others	Author	App has a function-ing game selection	5
REQ3	The user should be able to play a game that teaches them about the physiol-ogy of type 1 diabetes	The user needs to learn about the physiology of their condition to understand how to manage it	MD, Au-thor	App has a game that teaches physiology of type 1 diabetes	5

REQ4	The user should be able to play a game that teaches them about blood glucose management in the context of meals	The user needs to learn how to manage blood glucose levels when eating	MD, Author	App has a game that teaches blood glucose level management	5
REQ5	The user should be able to play a game that teaches them how physical activity affects blood glucose levels	The user needs to learn how physical activity affects blood glucose	MD, Author	App has a game that teaches the effects of physical activity on blood glucose levels	5
REQ6	The user should see their score after playing a game	Seeing your score increases motivation by providing a feeling of accomplishment	Author	Games display the score after a game session is finished	4
REQ7	The user should receive a number of stars based on their score	Seeing the number of stars increases motivation by wanting to get all the possible stars	Author, Designer	Game displays a number of stars after a game session is finished	4

REQ8	The game should remember the progress the user has completed and display it	It is annoying to lose all progress every time the game is closed and opened again	Author	Game stores user progress and displays it somewhere in the app	3
REQ9	The app should let the user choose a character design	Allowing the user to customize their character helps them relate to the character which increases motivation	Author	App lets the user customize their character	2
REQ10	The app should let the user unlock more character designs when they progress in the games	Allowing the user to unlock designs increases their motivation to do well	Author, Designer	User can unlock designs for their character by progressing in the game	2
REQ11	The app should be in Norwegian	Young children in Norway might struggle to understand if the text in the app is not their first language	Author	Text in the app is in Norwegian	3

4.4 Non-functional Requirements

Due to the young age and medical condition of the target group, some non-functional requirements were necessary.

4.4.1 Safety

There could be severe consequences if the application teaches the user erroneous medical information. Therefore, all information presented in the application must be accurate or not explicit medical information.

4.4.2 Security

It is important that the security and privacy of the users are preserved. The application should not store any identifiable- or sensitive data and should not communicate any such data with external components.

4.4.3 User Interface

The user interface (UI) of the application should be designed with the target group in mind. This involves:

- The UI should elicit positive emotions in the user
- The characters should be relatable to anyone, no matter age or gender.
- The UI should feel like a fun game, not a medical device

4.5 Summary

This chapter presents the functional and non-functional requirements used for the design of the project application. The chapter presented a persona representing the target group, called 'Newly Diagnosed David', a 9-year-old child with a recent diagnosis of type 1 diabetes. This persona was used to form scenarios and user stories, which could be used to form functional and non-functional requirements.

5

Design

5.1 Initial Concept

The initial concept of the solution was to build a cross-platform, gamified educational mobile application. The solution would use fun and interactive games to educate children about type 1 diabetes and how to manage it.

5.2 Title

The title of the mobile application is "DiaLudus". The name combines the Latin words ’diabetes’ and ’Ludus’. Diabetes refers to the disease. Ludus has multiple possible translations in Latin, such as *a play, game, diversion, pastime*. It can also refer to children’s education or *child’s play* [52]. The combination was chosen to represent how games can be used as a tool to educate children in a fun and engaging way.

Latin was chosen as the language for the title due to its connection and importance in science, especially in medicine. While the language is considered "dead", the language is relatively international due to being used in science. This means it is easy to pronounce by any person with a native language derived from Latin.

The name is also short and easy to remember, especially for diabetes patients,

which is beneficial for a brand as the user will not struggle to know what the app is called.

5.3 Character

The character chosen to represent the user in this solution is called 'Ludus'. Ludus is a character with the appearance of an innocent and happy slime. See Figure 5.1 for what one of the versions of Ludus looks like. Ludus can also be customized with variations of the same design.

Figure 5.1: Ludus, the character in DiaLudus application

Ludus does not have a specified gender, so users can relate to it regardless of gender. The character also takes away some of the severity of the disease by being a non-human cartoon design.

5.4 User Interface

Shneiderman and Plaisant [53] present some important guidelines for the use of color in UI design:

- Use color conservatively: Limit the number of colors.
- Be consistent in color coding.
- Use color changes to indicate status changes.
- Use color in graphic displays for greater information density.

These were all taken into account when designing the user interface for DiaLudus.

5.4.1 Color choice

Blue was selected as the main color for the application. Blue is often used in the healthcare sector, as it is posited to be relaxing, encourage focus, calm, and stable action [54].

5.4.2 Home screen

The mock-up for the home screen included the title of the application, two different variations of the game's character, and simple text-based buttons to navigate to the various parts of the app. See Figure 5.2 below:

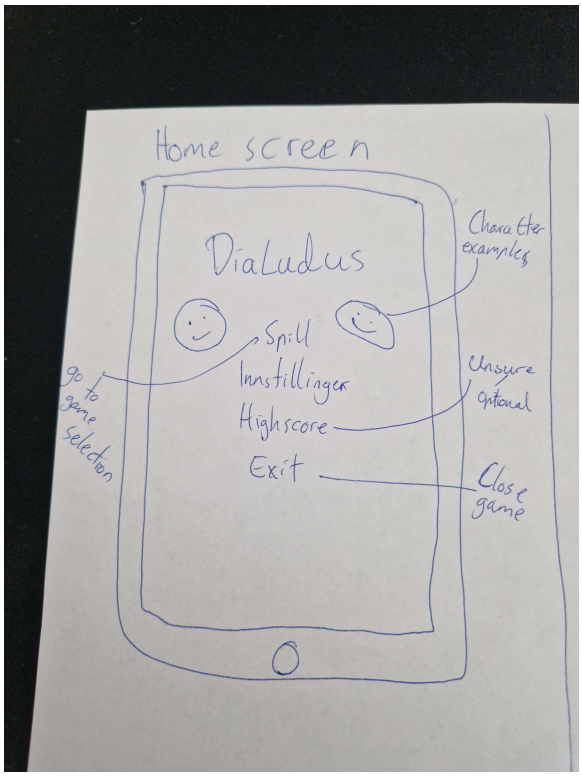

Figure 5.2: Mock-up of application home screen

5.4.3 Game Selection

The mock-up for the game selection screened included the game character and simple square buttons with the names of different games. Each button contains stars to show achieved progress. See Figure 5.3 below:

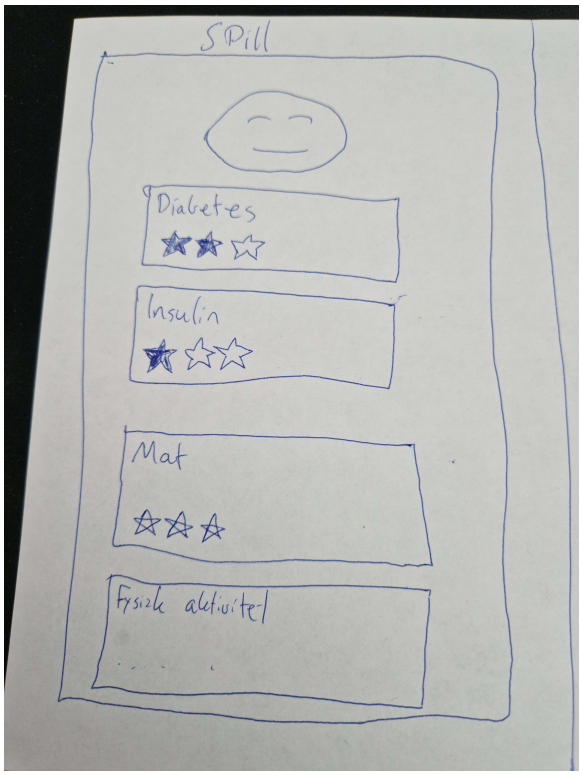

Figure 5.3: Mock-up of game selection screen

5.4.4 Settings

The mock-up for the settings page shows the option to change the selected character with arrows. See Figure 5.4 below:

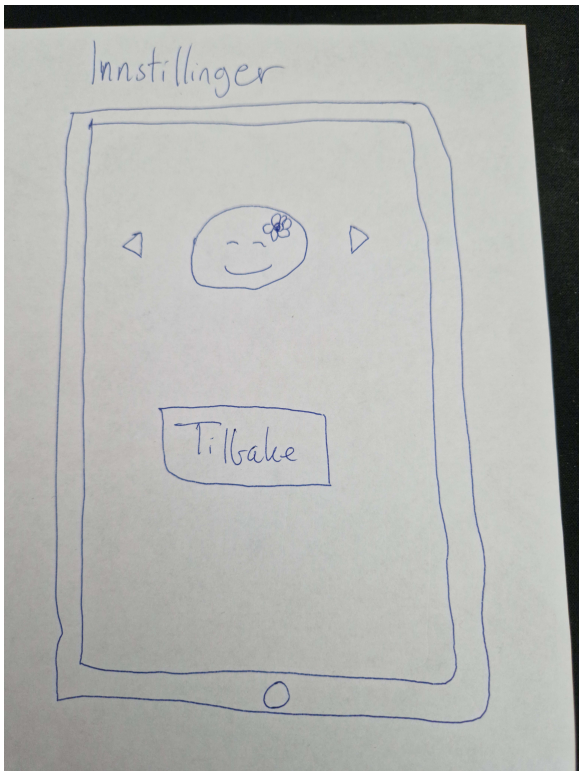

Figure 5.4: Mock-up of application settings screen

5.5 Games

5.5.1 Level 1: Introduksjon

The mock-up for the first module is simple and consisted of a character and a speech bubble, where the character introduces itself. See Figure 5.5 below:

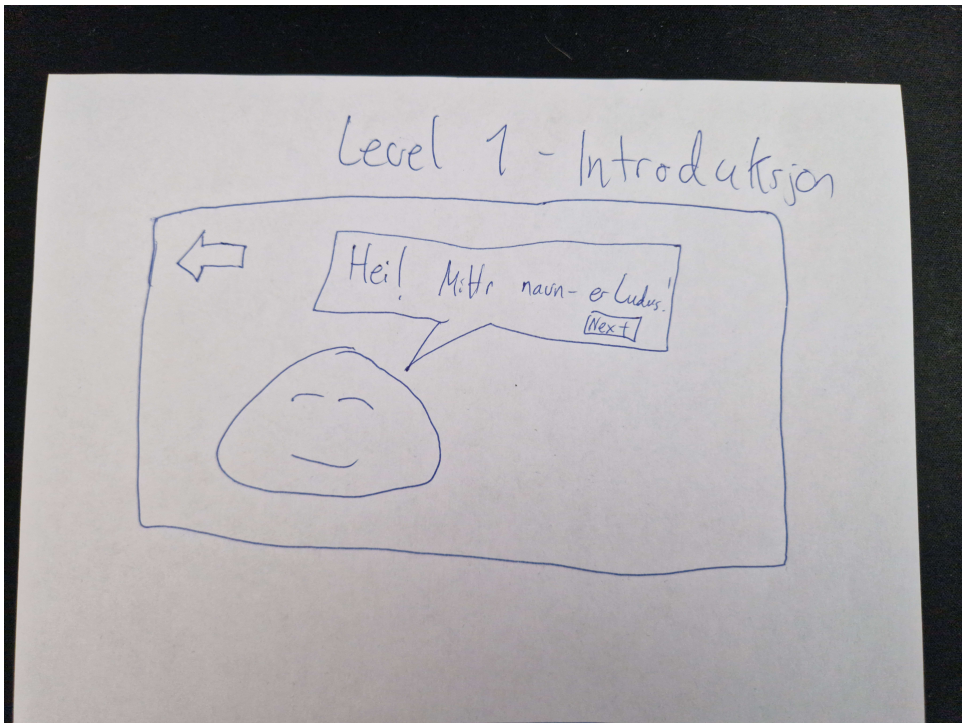

Figure 5.5: Mock-up of level 1: Introduksjon

5.5.2 Level 2: Galaktisk Glukose

The mock-up for the second game is more complex. The Ludus character is shown on the left, being controllable by dragging it up and down. Food is flying toward the character, and if it reaches the area behind the character, various things will happen based on the food type. A bar representing Ludus' blood glucose levels is depicted at the top. The character can lower their blood glucose levels by shooting insulin pens at the food. The button used to shoot is in the lower-right corner. See Figure 5.6 for a picture of the mock-up:

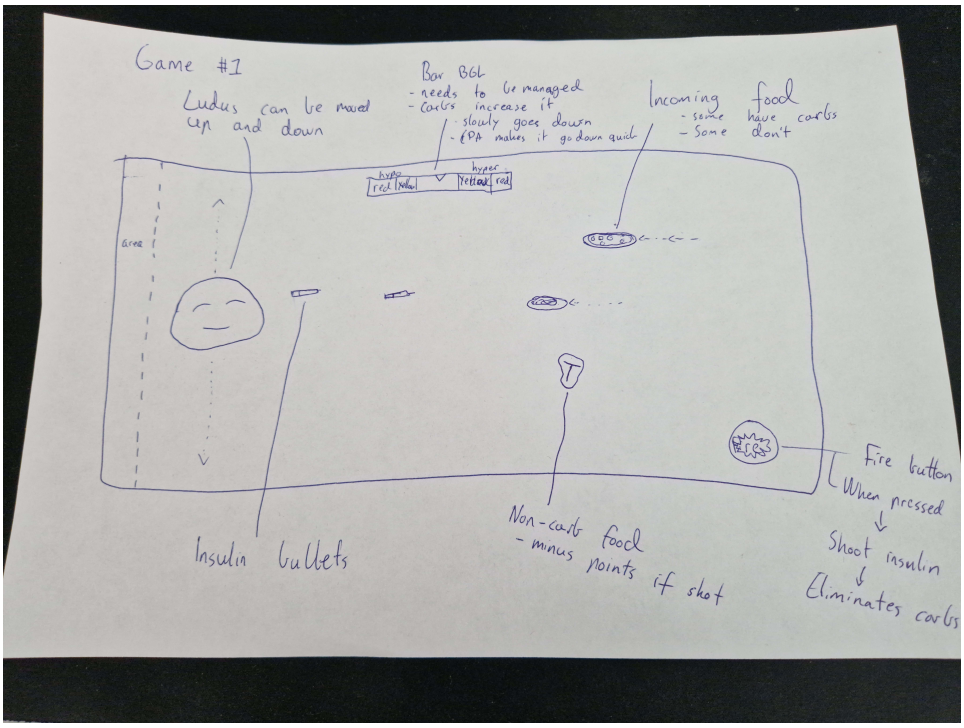

Figure 5.6: Mock-up of Galaktisk Glukose game

5.5.3 Level 3: Høyt eller Lavt

The mock-up for level 3 displays two pictures of food with carbohydrates. The text in the middle asks the user to select which is higher or lower in carbohydrates. At the top is a life and score holder. See Figure 5.7 for a picture of the mock-up:

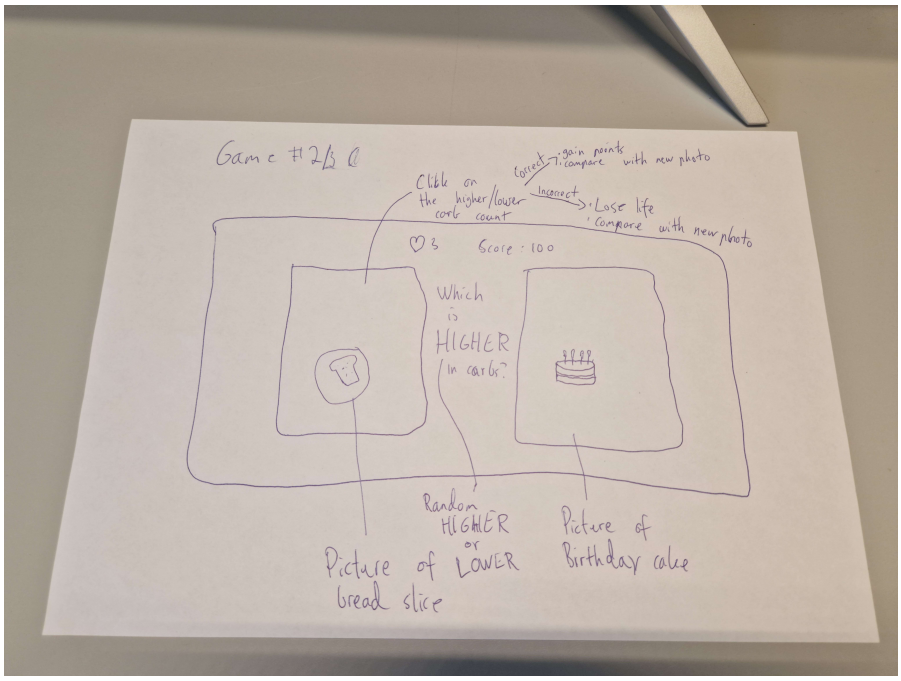

Figure 5.7: Mock-up of Høyt eller Lavt game

5.5.4 Level 4: Pakk Sekken

The mock-up for Pakk Sekken shows the character Ludus telling the user it is going on a hike or trip, along with a backpack and a series of items. Clicking on items that are useful for the trip increases the score. When the user has selected all necessary items, they can confirm they're finished by clicking the 'Done' button. See Figure 5.8 for a picture of the mock-up:

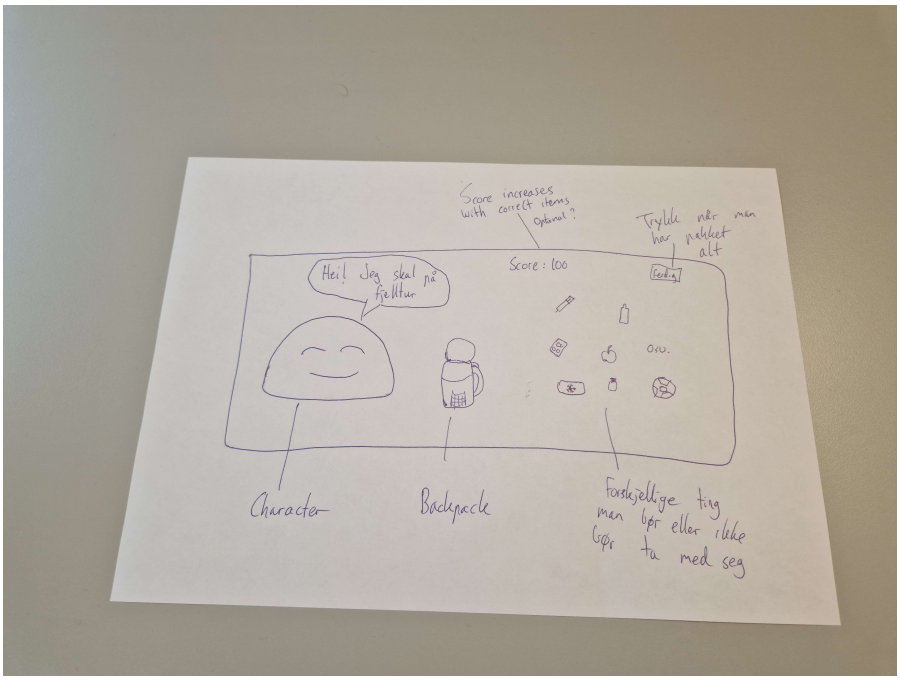

Figure 5.8: Mock-up of the Pakk Sekken game

5.6 Motivation and Rewards

An important part of designing such an application is to increase the user's motivation to use it. Multiple design choices were made to ensure this.

The design of the rewards system consists of three main features:

- The user can earn up to 3 stars for each level based on how well they perform
- The user can unlock unique and special skins for their character by earning stars
- The user's highscore is stored so they can see their progress

5.7 Summary

This chapter has described the design of the mobile application "DiaLudus." The chosen name combines the word diabetes with the Latin word for play and children's education, reflecting games as a fun and exciting learning tool. The character in the application is named 'Ludus'. It looks like a cartoon-style slime, which makes him relatable for all children while adding a relaxing and disarming look to the character, alleviating some of the seriousness of diabetes. The chapter describes the four games in the app: Introduksjon, Galaktisk Glukose, Høyt eller Lavt, and Pakk Sekken. These games educate the user on the basics of type 1 diabetes, including physiology and anatomy, blood glucose management, carbohydrate counting, and essential items for a person with diabetes on longer trips. Motivational design is incorporated through a star system that rewards the user based on their performance and allows them to unlock unique and cool cosmetics for their character by doing well in the games. All these factors provide an interactive and fun experience for children learning about type 1 diabetes and self-management of the disease.

6 Implementation

The application developed in this project is a prototype created in the Unity game engine. This chapter will present important implementation details of the prototype and explain why certain choices were made.

6.1 Solution Application

The application consists of several mini-games aimed at educating on the various parts of diabetes self-management. Each game can also be referred to as a module due to its modular design.

6.1.1 Main Menu

The main menu was designed to be simple but inviting. The game's title is displayed in a bold logo, colored by the same palette as the standard variation of the Ludus character. Two versions of Ludus are then displayed, with one jumping and in two different colors. This provides a playful and cozy feeling to the screen, while the jumping version makes the screen feel more dynamic. Simple text is used for the menu options, where users can press which component they want to navigate to. See Figure 6.1 for a screenshot of the main menu.

Figure 6.1: Design of the main menu in DiaLudus

6.1.2 Character Selection

The user interface for the character selection was kept simple. At the top of the screen is a title telling the user to select a character. The currently selected character is in the middle of the screen. The user can then cycle through various character colors and unique versions unlocked by achieving stars in the different games. See Figure 6.2 to see what it looks like.

Figure 6.2: Design of the character selection in the Settings page, displaying the unlocked 'King' skin.

6.1.3 Game Selection

The game selection page displays the selected character and the various games the user can play. Each game is represented by a card where the title of the game and the number of stars unlocked in that game is displayed. Clicking on one of the cards will take the user to the page for that game. See Figure 6.3 for a screenshot of what it looks like.

Figure 6.3: Design of the game selection in the Settings page.

6.1.4 Introduction

The first module aims to introduce the user to the application. The user is greeted by Ludus, who introduces itself and explains that it has type 1 diabetes. It then provides some basic information about the physiology and anatomy of type 1 diabetes while intermittently asking the user questions to gauge their knowledge level. The score is calculated at the end based on how many correct answers the user had. See Figure 6.4 for a screenshot of one of the questions being asked.

Figure 6.4: Ludus prompting the user about where insulin is produced

6.1.5 Galactic Glucose

Galactic Glucose was chosen as the name for this game due to being inspired by the video game genre "Shoot 'em up". This genre has various definitions, but this game resembles the 'Fixed shooter' genre where the player's movement is locked on one axis, and multiple incoming targets must be shot. The most well-known version in this genre is Space Shooters, which is why the alliteration of Galactic and Glucose became the title [55].

Galactic Glucose is more complicated than the other games and therefore has an additional step when you choose it in the game selection. An informational card shows up instead of taking the user directly to the game. The informational card explains the game's concept to the user so they are prepared to start playing. See Figure 6.5 for a screenshot of the card's appearance.

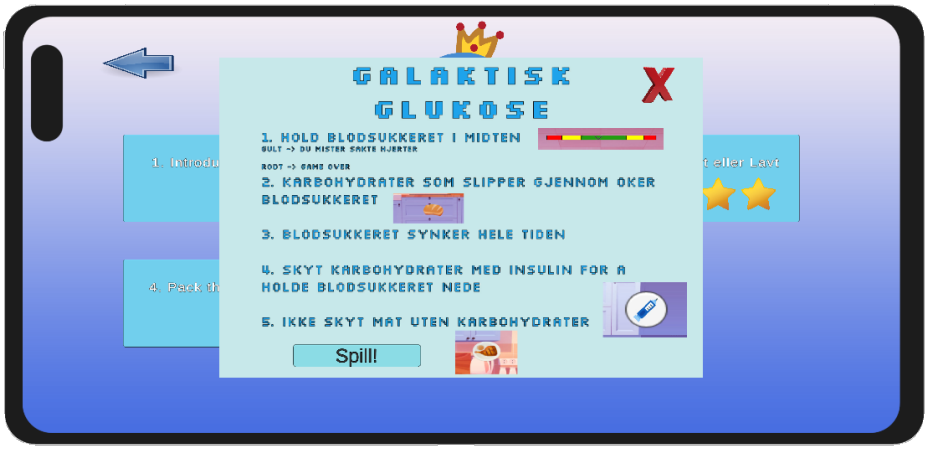

Figure 6.5: Informational card shown after selecting the game 'Galactic Glucose'

Galactic Glucose is a game about managing the blood glucose levels of Ludus. At the top of the game is a bar representing his blood glucose levels. The game's key point is to keep the arrow within the green section of the bar. The arrow is decreasing slowly.

Various food items come flying towards Ludus from the right. Some are carbohydrate heavy food items, such as bread and pasta. Others are protein-rich foods, like a grilled chicken thigh. Carbohydrates that go past Ludus give a spike in blood glucose levels, meaning the arrow moves suddenly to the right. Allowing protein to move past Ludus increases the score.

A button in the bottom-right corner allows Ludus to shoot an insulin pen at the incoming food. Shooting the protein gives negative points, and shooting the carbohydrates destroys them. However, it is important to let some carbohydrates through, or else the arrow will go too far left.

The heart counter next to the bar will start ticking down every second the arrow is in the left corner. The game is over if it reaches zero. This mimics the consequences of blood glucose levels outside the normal range, but it is not an immediate threat to a patient's life. However, if the arrow reaches the red zones, the game is instantly over, as specific values are too critical. The arrow can go too far on either side to represent hypoglycemia and hyperglycemia. See Figure 6.6 for a screenshot of the game.

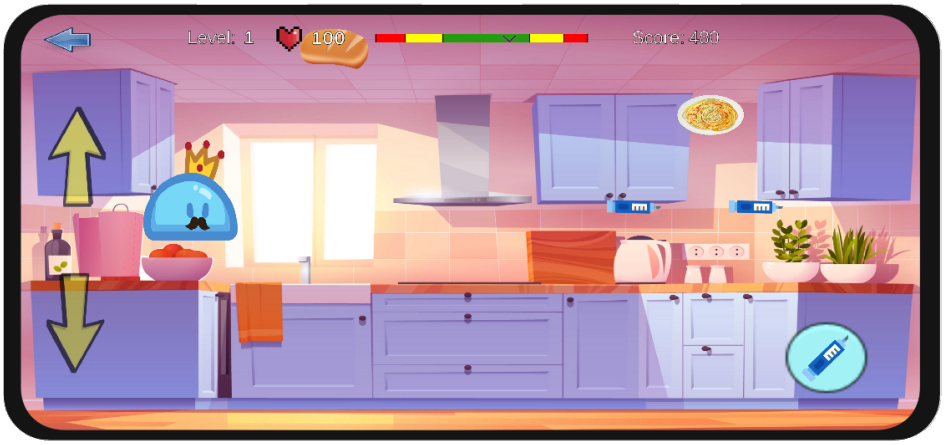

Figure 6.6: Screenshot of the Galactic Glucose game, with the unlocked 'King' skin

6.1.6 Høyt eller Lavt

The third game is 'Høyt eller Lavt', translated to 'High or Lower' in English. The game design is based on the popular browser game titled 'The Higher or Lower Game' [56]. The original game presents two popular Google searches, providing the average number of monthly Google searches for one of them, and prompts the user to choose whether the second term has more or less average monthly Google searches.

The Høyt eller Lavt game randomly presents two pictures of food. It then asks the user to click on the picture with the least or the photo with the most carbohydrates. Both options have a 50/50 chance of being displayed for every guess. See Figure 6.7 for what the initial two choices look like.

Figure 6.7: Initial two choices in the Høyt eller Lavt game

The user receives visual feedback based on whether they make the correct choice or not. Correct answers will display a green checkmark, and their score will increase. Incorrect answers will display a red X, and they lose one heart. The actual count of carbohydrates in both pictures will be displayed after their answer. The user can then press the 'Next' button to move on to round two, where the option they chose remains, and the other picture is switched out with a new random food image. The game continues until the user is out of food or has gone through all of the photos. See Figure 6.8 for what it looks like when the user chooses the correct answer.

Figure 6.8: User chose the correct answer and receives visual feedback of it

The number of carbohydrates in each picture is calculated using a mobile application for people with diabetes called 'Carbs & Cals', which provides detailed nutritional information for food and allows the user to select portion sizes to adjust it [57].

6.1.7 Pakk Sekken

The last game is titled 'Pakk Sekken', meaning 'Pack the Bag' in English. Its purpose is to educate the user on essential items to bring when going on longer trips or hikes—a popular pastime in Norway. The Ludus character tells the user it is going on a hike and needs help packing his bag. The user can then select important items by clicking on them, and Ludus explains why they are useful to bring along. There are also red herrings, i.e., items that are not necessary, such as a goldfish. The game ends when all the correct items have been selected, or the user picks an incorrect item. See Figure 6.9 for a screenshot of the game.

Figure 6.9: Screenshot of the Pack the Bag game

6.1.8 Highscore

The Highscore page portrays the user's highscores on the four games in the application. It also presents the option to reset all progress in the game, including highscores, earned stars, and unlocked skins. See Figure 6.10 for a screenshot of the page.

Figure 6.10: Screenshot of the highscore page in the application

6.1.9 Stars

Every level rewards the user with stars based on their performance in the game, ranking from zero to three stars. The calculation of how many stars depends on the game in question. For example, the first game gives stars equal to the number of correctly answered questions, while galactic glucose gives stars based on which stage they got to. The last two games give stars based on the relationship between the achieved score and the maximum achievable score. See Figure 6.11 for an example of what it looks like when a game is over, and stars are awarded.

Figure 6.11: Example of stars awarded after the user finishes a game

The number of stars achieved on a level is stored on the device and displayed in the game selection menu. You can see Figure 6.3 displayed previously, as it displays three stars on Galactic Glucose and Høyt eller Lavt.

6.1.10 Rewards

It is vital to encourage good behavior with rewards, and providing the opportunity to unlock more customizability to their character is an effective tool to both encourage and motivate the user to play, according to the findings in Subsection 7.1.3. As mentioned in Subsection 6.1.2, the user can select a few colors for their character from the beginning. More skins are unlocked as rewards once they score high enough in the different games. These skins have more detail to them and change the size and shape of the character as well, making them a fun and exciting option to unlock while letting the user personalize their experience.

6.2 Project Structure & Assets

The asset workflow is an important part of working in Unity. Assets are any items used to build the application, such as images, sprites, sound files, and scripts. Therefore, the organization of the assets is equally important.

All assets fall under the Asset folder and are sorted into their own folders.

6.2.1 Scenes

A scene in Unity is where you work with all of the content presented to the user in a game, much like a theater scene in real life. It contains a camera that determines the view the user has and all GameObjects used to create the scene. Every object in a scene is a GameObject, and these are the building blocks of Unity, ranging from the main camera, lighting, sprites, text, and prefabs. GameObjects are assigned different properties based on what you want them to do, and their order in a scene determines how they are displayed. GameObjects can also be activated to be visible and interact with the game or deactivated, stopping them from being rendered and performing calculations [33]. See Figure 6.12 for a screenshot of how GameObjects are used to form scenes in Unity. The greyed-out names are GameObjects that have been deactivated.

Theoretically, one can create an entire game in one scene, which can be ideal

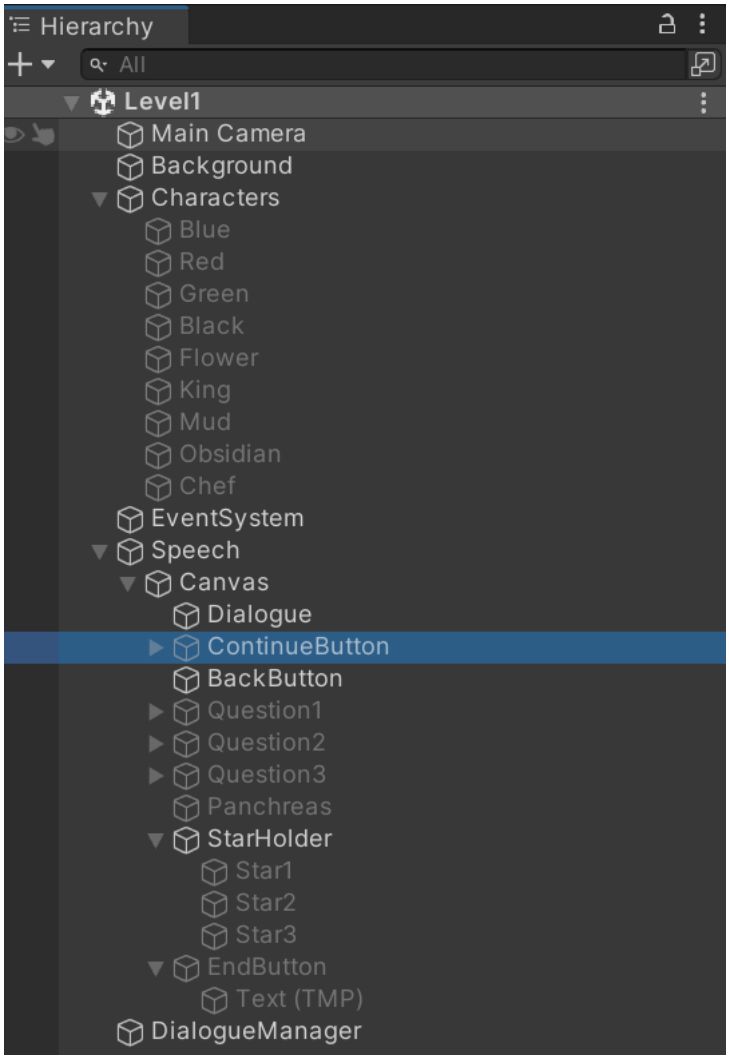

Figure 6.12: Hierarchy of GameObjects in the scene for Level 1 of the game

for rudimentary applications, but runs the risk of introducing unnecessary complexity, poor readability, and maintenance issues [33]. The solution follows Unity conventions and has one scene for each game and a separate menu in the application. This ensures that each scene remains readable, simple, and isolated from other scenes.

6.2.2 Scripts

A vital structure to notice are how scripts are created and stored. Each script is a C# file that handles logic through code. The design convention used in this project was to keep the scripts as small as possible and responsible for controlling their own mechanics. This way, script changes are isolated, reducing the chance of unforeseen bugs.

Scripts that can be used freely in any scene are located in the initial Scripts folder. Scripts specific to a scene that can not be used outside the scene without critical consequences are placed within a folder for that scene. For example:

```
Assets\Scripts\Level1
```

6.2.3 Data State

Reducing stored data to the bare minimum was an intentional design choice to preserve the privacy of the users. The only data stored on the device measures progress, such as stars unlocked on each level, characters unlocked, and high-scores per level. The data is stored using the Unity-provided PlayerPrefs feature. PlayerPrefs is a local key-value registry that allows the storage of strings, integers, and floating-point values. PlayerPrefs was chosen over a traditional database for its simplicity and small size. Values can easily be written to and read from storage using a key that maps a name to a stored value [33].

6.3 Camera & Canvas

The entire game is designed as a side-on 2D game, meaning the camera angle is directly from the side. The camera object was also set to be orthographic, meaning that it does not differentiate how graphics are rendered based on the depth of the objects [33]. While this is not as important for a side-on 2D game, it was convenient as it maps to the screen size and most forum debates on which to use usually come down to personal preference in this specific case.

The canvas is a Unity GameObject representing the abstract space in which the user interface is laid out and on top of the camera. All items that are the child objects of a canvas object will be rendered on top of everything else. The canvas also allows the user interface to automatically scale to the screen size of whatever device runs the application. This implementation scales the UI based on screen width and uses the screen resolution of the test device as the reference resolution to scale it off.

6.4 Extendable Components

The implementation was designed with the mindset of making the application extendable. Due to the time constraint of the project, the application was intended to be a prototype or proof-of-concept, with the hope that someone would continue on it in the future. Therefore, the application was implemented with the mindset that it should be easy to extend should someone decide to do so.

6.4.1 Introduction

The dialogue system in the introduction is easy to edit, extend, or shorten due to how it is implemented. The script used for the dialogue system contains a string array that holds sentences. The initial declaration defines the first sentences that should be displayed. A coroutine method in the script then uses that array to display each sentence character-by-character, which adds a visually appealing dialogue system where the text is gradually displayed akin to someone talking. Coroutines in Unity allow you to pause execution and return control to Unity, but continue on the next frame, which is perfect for animations [33]

When one dialogue sequence is finished, the array mentioned earlier can be updated with the next group of sentences, and the same method can be called again.

6.4.2 Høyt eller Lavt

The assets used in the game Høyt eller Lavt are PNG files of food with an associated carbohydrate count. To make the game easy to extend, each photo asset is titled after its carbohydrate count. For example, the photo for a slice of bread is titled ’15.png’, containing 15g of carbohydrates. When the script compares the two pictures in a round to determine whether the user answered

correctly or not, it simply compares the names of the image objects, as Unity removes the file extensions from the name.

```
int carbA = Int32.Parse(imageA.sprite.name);
int carbB = Int32.Parse(imageB.sprite.name);
```

This ensures that new photos can easily be added without any changes to the code or the Unity editor, as long as the file-naming convention is maintained.

6.5 Summary

This chapter has described the implemented system prototype and important implementation details. The resulting solution from the design is a functional cross-platform mobile application with several mini-games that teaches the user about type 1 diabetes and self-management of the disease. The chapter also describes implementation choices meant to ensure that the application is easily extendable in the future.

7

Results

7.1 Literature review

The literature search identified 83 studies after duplicates were removed. Initial screening excluded 61 studies, resulting in 22 studies assessed for eligibility. Out of the 22 studies, 15 were excluded for various reasons, resulting in 7 studies being included in the qualitative synthesis. See Figure 7.1 for an overview of the screening process.

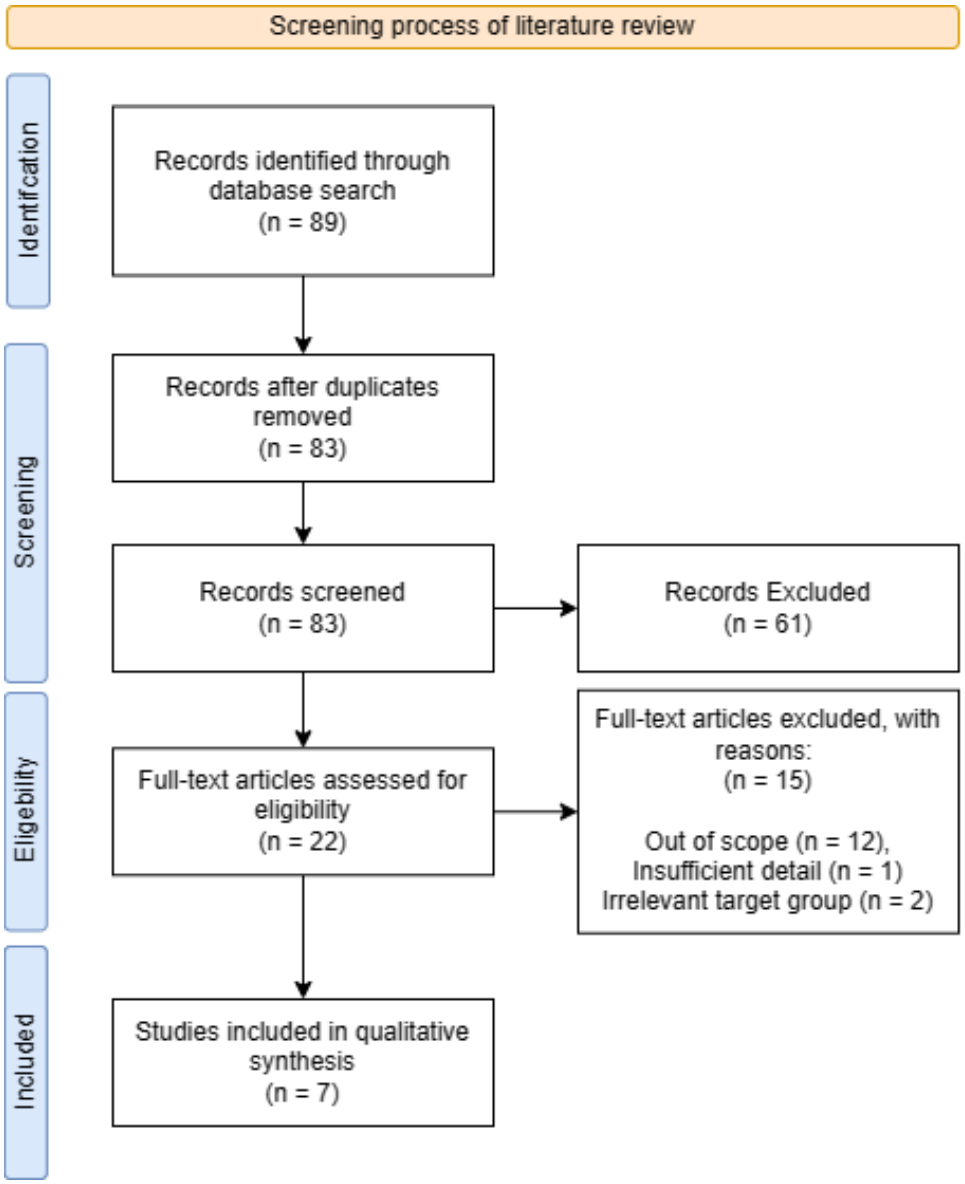

Figure 7.1: PRISMA-diagram for the screening process in the literature review

As stated in Section 3.1, the search yielded seven studies on educational mobile games for children with type 1 diabetes. See Table 7.1 for an overview of the included studies.

Table 7.1: Overview of the studies included in the literature review

Author	Title	Year
Bassilious, E. et al.[58]	Power defense: a serious game for improving diabetes numeracy	2012
Bernier, A. et al.[59]	New-Onset Diabetes Educator to Educate Children and Their Caregivers About Diabetes at the Time of Diagnosis: Usability Study	2018
Brox, E. et al.[60]	User centric social diabetes game design for children	2012
Chen, G. et al.[61]	Designing games to educate diabetic children	2011
Chomutare, T. et al.[62]	Play and Learn: Developing a Social Game for Children with Diabetes	2016
Nørlev, J. et al[63]	Using Distance Communication for the User-Centered Development of a Smartphone-Based Serious Game for Children With Type 1 Diabetes: Participatory Design Approach	2022
Nørlev, J. et al.[64]	Game Mechanisms in Serious Games That Teach Children with Type 1 Diabetes How to Self-Manage: A Systematic Scoping Review	2022

7.1.1 Important Design Factors

As stated in Section 1.2, the first research problem ***RP1*** attempts to discover what design factors are important to take into consideration when designing a gamified mobile application for children with type 1 diabetes. This section will present the findings of the included studies on this problem.

Bassilious et al. [58] state that children often deem traditional teaching methods boring, such as pamphlets and other reading material. They state that children prefer actively participating in the teaching process and seeking interactive solutions. The study concludes that video games are an effective learning method for this target group. It also concludes that the development process should involve experts on diabetes, education, and technological development and must be based on the learning needs and desires of the target group.

Bernier et al. [59] emphasize the inclusion of multiple disciplines in the development stage, such as pediatric endocrinologists, diabetes educators, and dietitians, in addition to the standard development team of artists and programmers.

Brox et al. [60] state multiple important factors when designing a game for

children with diabetes, such as the children needing the consent of their parents to play; no violence or adult language; player avatars cannot die; the game must appeal to all genders; the possibility to practice diabetes tasks in the game; no storage of medical or sensitive information; no personal medical advice; a social game, but an option to play alone; predefined dialogues.

Chen et al. [61] state three critical factors to take into consideration: adjustable difficulty based on the patient's knowledge level; the game should provide concrete feedback about their performance, and the performance should be tied to the patient's skill of self-management; the game should contain a variety of challenges with increasingly complex knowledge acquisition.

Nørlev et al. [63] state that it is vital to include children with type 1 diabetes in the development of the application. They also put a secondary emphasis on including other stakeholders, such as the parents and healthcare workers.

Nørlev et al.[64] stated it is important to include multiple game mechanics when developing a gamified application for education on type 1 diabetes to children. See the reprinted screenshot from Figure 7.2 for how they used this when designing their main menu in their related project.

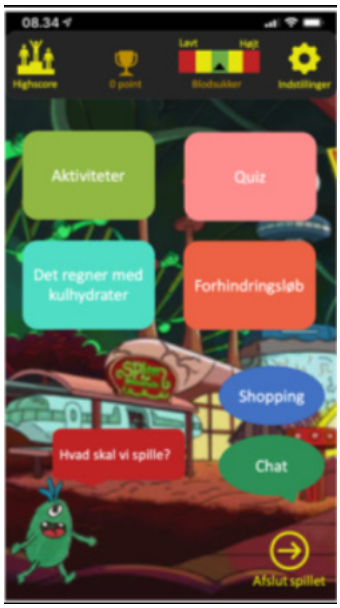

Figure 7.2: Multiple game mechanics displayed in the main menu [64]

Chomutare et al. [62] emphasize the importance of not making competitive games with multiplayer- or cooperative mechanics a zero-sum game. It is better to ensure that all players can benefit without any conflict between each

other.

7.1.2 Necessary Medical Knowledge

As stated in Section 1.2, the second research problem attempts to discover what medical knowledge is essential to educate children with type 1 diabetes. This section will present what knowledge the solutions in the included studies attempt to pass on to the users.

The video game presented by Bassilious et al.[58] focuses on diabetes numeracy, which is the ability to understand and interpret numerical results and then perform the right actions based on those results to manage diabetes. In other words, the game focuses on teaching children about blood glucose management. They also educate the user on understanding nutritional labels on food items.

The solution presented by Bernier et al.[59] is split into eight modules that cover basic diabetes self-management topics such as what diabetes is, glucose monitoring, insulin, hypoglycemia, hyperglycemia, nutrition, exercise and diabetes, and personal management plans.

The video game presented by Brox et al.[60] is designed to teach children with type 1 diabetes about exercise, nutrition, glucose monitoring, and insulin treatment.

The video game presented by Chen et al.[61] is designed to teach children with type 1 diabetes about appropriate food choices, insulin injection, and regular exercise.

The mobile application presented in Nørlev et al.[63] focuses on teaching children about the effects of carbohydrates on blood glucose levels.

7.1.3 Motivation

As stated in Section 1.2, the third research problem attempts to discover what techniques and tools can increase the patient's motivation to use the application. This section will present the information the included studies provide to answer this question.

Bassilious et al.[58] emphasize that the most important methods for increasing motivation are to make the game **fun** and **challenging**. Their method for ensuring this is to design their game as a tower-defense game, which they claim

is a popular sub-genre of real-time strategy (RTS) games. They also use other techniques, such as providing the user with various ways to win, purchasable upgrades, and wagers.

Bernier et al.[59] use the following tools to increase motivation: interactive animations, short cartoons, demonstration videos, and simple games. They put extra emphasis on interactivity as a motivational factor of educational games. See for a demonstration of how they used interactive animations to show the relationship between blood glucose levels and insulin dose. See Figure 7.3 reprinted from Bernier et al.[59]

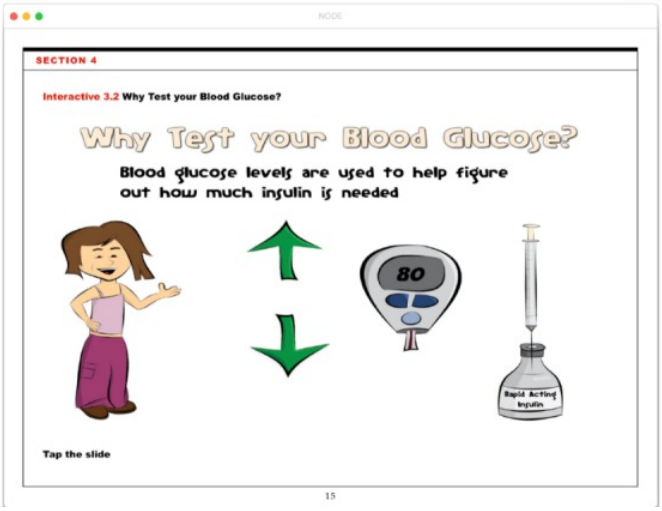

Figure 7.3: Interactive animation in NODE application [59]

A key concept presented by Chen et al.[61] is the "flow" of the game, which in this context refers to the level of intensive involvement by the user in a game. They also emphasize giving proper feedback to the user while making it challenging for the player.

Chomutare et al.[62] emphasize cooperation instead of competition, social comparison, and focusing on positive achievements.

Nørlev et al.[63] used multiple methods to increase engagement and motivation, such as a narrative context, feedback, avatars, simulation, goals, levels, and social interactions.

7.2 Interview with healthcare workers

One medical doctor met with the author for a semi-structured interview about the education of children with type 1 diabetes. The interview took place at the UiT campus on the 31st of March and lasted approximately 30 minutes. To preserve the privacy of the medical doctor, they will from now on be referred to as either 'they' or 'the doctor.'

7.2.1 Necessary Medical Knowledge

What is the most important information that the patient needs to learn early?

The doctor commented that it was a broad question with a broad answer and first deemed it necessary to explain that the diagnosis process for children developing type 1 diabetes varied greatly, which also affected their education. Some patients have subtle symptoms that lead to a diagnosis while they remain relatively healthy, while some have to be hospitalized under intensive care. This means that those patients with milder symptoms can more gradually receive the information than more acute cases.

The doctor commented that the treatment of type 1 diabetes in children is changing as the healthcare system transitions to relying more and more on technological solutions, such as CGMs, insulin pumps, and closed-loop systems. The doctor stated that one of the most important things to learn because of this was a simple understanding of the physiological effects of diabetes, especially how insulin works in the body.

> "(...) So in this spectrum (referring to various technological tools), there is a lot one needs to learn, but if I had to say what is most important, it would be to understand the physiology of how insulin works in this body. That is what we are trying to simulate here (again, referring to the tools)."

The doctor explained that this included understanding how the body constantly produces insulin throughout the day, referred to as basal insulin, which is slightly affected by sleep and activity. However, they meant it was more important to focus on insulin in the context of meals and learn the correlation between the consumption of carbohydrates and insulin injection.

> "Where we put most of our effort is meals, especially learning to manage blood glucose levels by administering insulin and adjusting the dose based on the amount of carbohydrates. So you can sort of

> split it into two: the basal context and the quickly-working insulin for the meals."

The doctor summarized the answer by stating that meals were probably the most important knowledge for the patient to learn early but also emphasized that they want to look at the greater picture of self-management.

> "Blood glucose levels will be unpredictable no matter how good you are at self-management, so it is important to know how to manage high and low blood sugar."

To avoid hypo- and hyperglycemia, the patients are heavily encouraged to adopt a consistent routine, which makes blood glucose levels more predictable.

"**What do they need to know about nutrition?**"

The doctor first said that they taught the patients early about counting carbohydrates in a meal. Then they needed to understand that carbohydrates are not all equal.

> "There are many details to learn about carbohydrates. Some work quickly, and some take longer to work, but understanding carbohydrates and counting them is certainly central to their education."

What do they need to know about physical activity?

The doctor explained that learning about physical activity and its effect on blood glucose levels is an essential part of everyday life for diabetes patients.

> "Part of our education program is to have a physical activity session with a physical therapist, where they are wearing a continuous glucose monitor to see the effect in real-time. Put simply, physical activity has the same effect as insulin. If you do a heavy exercise session with the large muscle groups, you can obtain the same effect as administering bolus insulin in that you can draw glucose into the cells from the blood sugar."

The author pointed out that intense exercise can increase blood glucose levels, as adrenaline stimulates the liver to release glucose into the bloodstream. The doctor confirmed that this was also part of the children's education. They then explained that the patients are explained how various situations may affect blood glucose levels, like stress and intense activity.

> "It is difficult to pack a lot of information into a small period of

> time, especially for children who are dealing with the diagnosis on top of everything, but these things also come up in follow-up consultations where we look at situations where the blood sugar got out of control and discuss possible reasons why that happened."

What do they need to know about blood glucose management?

Since the conversation surrounding the previous questions had provided enough information on this topic, a follow-up question was asked instead.

Do they start immediately learning how to use CGMs and insulin pumps?

The doctor said it was a relatively new routine at their clinic, but their goal is that every child should have a CGM during the first visit. However, children aged 2-4 are given insulin pumps as well. He also made sure to emphasize that it is a challenging process.

> "There are technological tools that need to be synced to cloud services, you have compatibility issues with phones, and there are many things that must work. Then you have to teach them how to use all of this. The government also has guidelines on the equipment that should be used, but we have to help them decide what equipment is best for their needs."

A follow-up question was then asked.

Are they taught how to use finger prickers to measure blood glucose levels and insulin pens as a backup solution?

The answer was that this was the case. A lot can happen when the children are not in a situation where they can visit the hospital, such as going on vacation. In these situations, they must be capable of using the old methods to manage their blood glucose levels.

What knowledge do you think produces the best long-term results?

The doctor agreed that the more information the children had, the more control they could take over their condition and the better their self-management and prognosis. They also pointed out that it was a very interesting subject and varied based on the patient.

> "Some children receive the diagnosis at a very young age, where leaving self-management to them is completely out of the question. Another situation might be a teenager who gets it later, who has the

> appropriate knowledge and routines but struggles with motivation and feels different from those around them."

For the younger children, they suggested that information about insulin surrounding meals was the most important, but that learning how to use the technology correctly was also very important.

The doctor also pointed out that type 1 diabetes can develop regardless of socioeconomic status, meaning some kids might have a highly educated parent who works with IT and can build customized tools to aid them. In contrast, other parents might be technologically illiterate. This will also affect the patient's situation; some might have to learn more about themselves than others.

What are the people around the patient taught

The parents receive funding to educate kindergarten or the school the patient attends. The diabetes nurses at the clinic are available to assist them, but ultimately it is the parents' responsibility. This results in varying levels of knowledge for those around the patient.

> "We experience large variations. Like, some schools might have a teacher with diabetes who takes extra responsibility, while others might be vaguer and feel unsafe about taking responsibility for a student's health."

Is there any knowledge a patient should learn that we have not talked about so far?

The doctor said that we had discussed the most important knowledge but wanted to point out that it can be very difficult for some to learn about the physiology involved in diabetes and that there were probably a lot of technological tools available that the healthcare services are not utilizing. They explained that they have educational material they can give out, but it is often dated and old-fashioned, so using newer material would be beneficial. They also suggested using things like virtual reality and games as promising tools.

7.3 The Designed Application

The resulting solution from this project is a cross-platform educational gamified mobile application designed to teach children about type 1 diabetes. The application consists of four mini-games that teach various aspects of type 1 diabetes and self-management of the disease and a reward system to increase

motivation in the user to utilize the application.

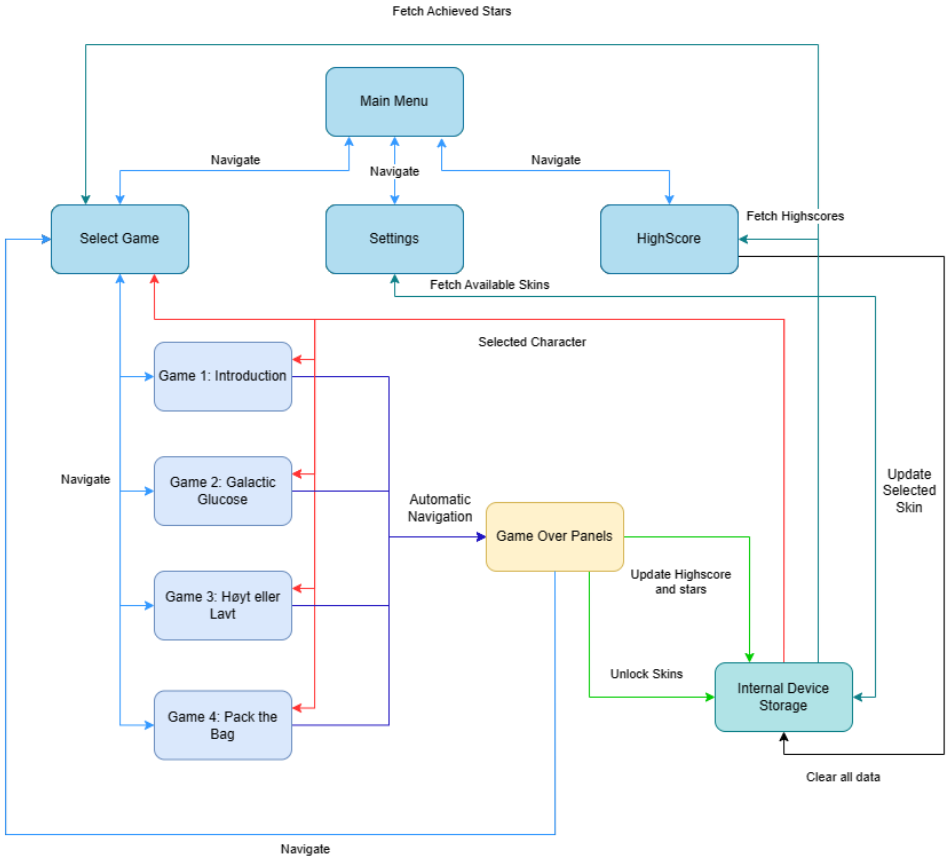

Figure 7.4: Flow-chart of the internal logic in the DiaLudus application

See Figure 7.4 for an overview of the application's internal logic. The app provides an interface for the user to navigate the various components of the application, displayed by light blue lines. The program's state is stored in the device's internal storage provided by Unity. Various modules in the system fetch data from this storage, including fetching highscores, available skins, and achieved stars. The user also has the option to completely reset the app by clearing the storage. Finishing a game takes the user to 'game over' panels, which update highscores and stars and unlocks skins if they do well enough.

7.4 Usability Evaluation

The recruitment of testers for the usability evaluation yielded three participants from the target group, ages 9 and 12. The first participant reported testing the

application for approximately 12 minutes. The second participant reported testing the application for about 6 minutes. The third participant reported testing the application for 30 minutes.

7.4.1 SUS Scoring

The answers to the SUS questionnaire lead to a numerical score for each question. The minimum value a question can receive from one user is 0, while the maximum value is 4. The creator of the SUS questionnaire recommends not to emphasize the result of a single question but the final score. The results of the individual questions can be seen in Figure 7.5, where the maximum achievable score for each question is 12 (four per question and three participants). The participants aged nine are denominated as P1 and P2. The participant aged 12 is denominated as P3.

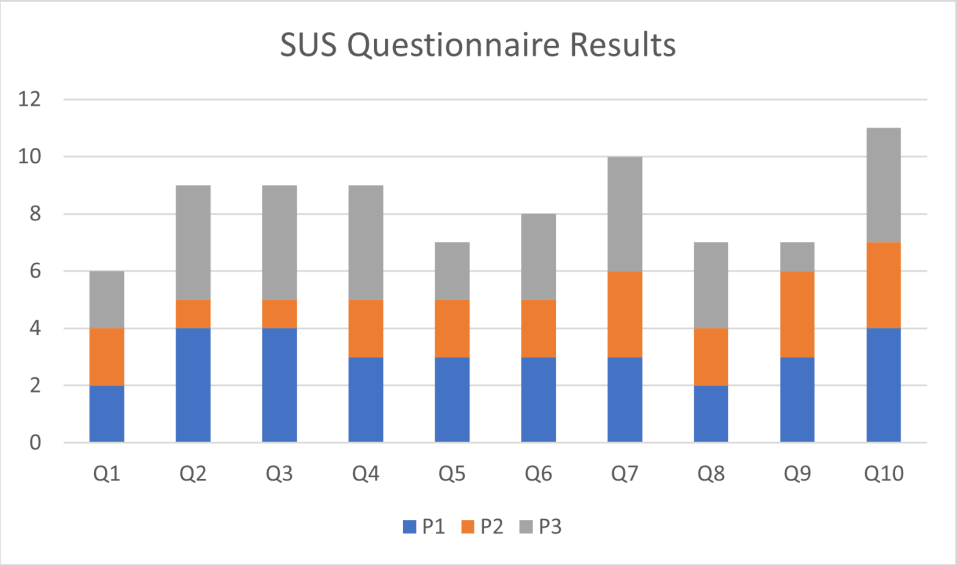

Figure 7.5: SUS questionnaire results by question

To get a SUS score per participant, the values of each question are multiplied by 2.5 and then summed up. The final score of the application is then the average of the participant's values. The participants evaluated the application with the scores [78.0, 53.0, 78.0]. The average score, and therefore the final SUS score of the application, is **69.7** (rounded up to one decimal). See Figure 7.6 for an overview of the SUS scores.

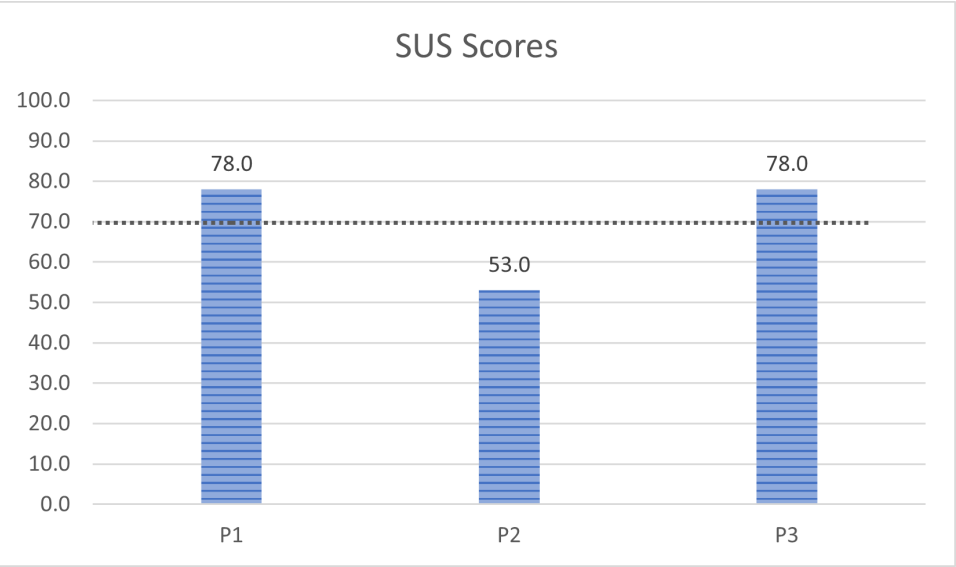

Figure 7.6: Final SUS score from each user with a dotted line to present the average score

7.4.2 General Feedback

The questionnaire used for the evaluation also included some questions to which the participants could respond with text. The answers to the questions were:

Would you use such an application if it was available when you received the diagnosis?

P1 said yes, while P2 answered:

> "Very good idea as an educational platform for children. Especially the quiz was good. The game was fun but perhaps not as educational. Would maybe use it, men then the user interface would have to improve." (Translated from Norwegian to English).

P3 stated that they would use it in the early phases of diagnosis.

For whom do you think such an app would be useful?

P1 answered that they thought it would be useful for patients with type 1 diabetes. P2 answered that it would be useful for children aged approximately 5-13 years old. P3 answered that it would be useful for children newly diagnosed

with type 1 diabetes.

Do you have any other forms for feedback you would like to provide?

P1 answered that they wished there were more games. P2 did not answer this question. P3 stated that they would like to see a more modern layout to appeal to children but did not specify any further on what they mean by this or how to improve it.

Further discussions about the results can be found in the next chapter.

7.5 Knowledge Transfer

Six students aged 23-25 participated in the knowledge transfer assessment. Each participant received numerical points for their answers on the test, with a maximum of nine points. The points achieved will be presented in percentages of the maximum achievable score.

All participants showed significant improvements after testing the application. The mean score before testing the application was 55.5%. The mean score after testing the application was 93.5%. See Figure 7.7 for a comparison of the scores achieved before and after testing the application.

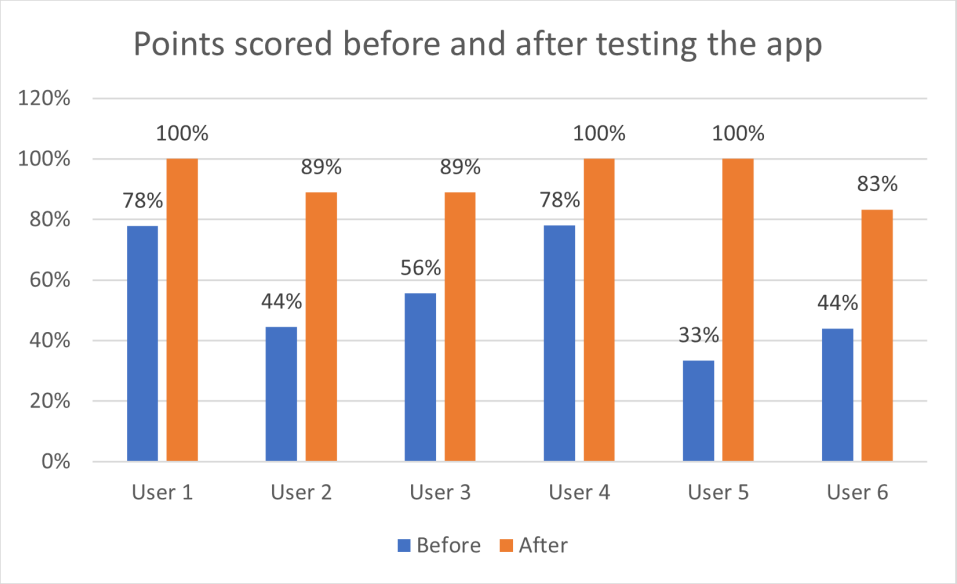

Figure 7.7: Knowledge transfer assessment scores showing test scores presented in percentage of the maximum possible score

7.6 Research Group Feedback

This section will present the feedback given by the research group during the presentation of the application. 12 members of the group were present.

Some in the audience considered the blood glucose level bar at the top of the galactic glucose game too small. They felt like it should be larger, as managing that was the key aspect of the game. One member even suggested that the background in the game should be replaced by a large-scale bar instead.

One researcher pointed out that using text might prove difficult for the youngest kids, as reading capabilities vary from child to child.

It was pointed out that correct and wrong answers should receive more visual feedback, such as lighting the answer up in green or red. This also applies to unlocking new skins, as explicit feedback about unlocking a skin is only provided in the first level. Further levels do not provide any notification of such.

One researcher felt that shooting insulin at the food could be confusing and suggested that the food colliding with the user could be more intuitive for users. Another researcher disagreed with that opinion and considered it intuitive and natural to the gameplay, but stated that the food flying past the character affecting blood glucose levels was confusing. They suggested food colliding with the user to affect blood glucose levels instead.

One researcher pointed out a minor spelling error.

7.7 Medical Doctor Feedback

This section covers the feedback from the two medical doctors who tested the application. The doctors will be referred to as Medical Doctor (MD) #1 and MD #2. For how testing was performed, see Section 3.10 for how testing was performed.

Medical Doctor #1

MD #1 started by praising the application, thinking it was well-made and did a good job at what it was designed to do.

Regarding Module 1: Introduction, MD #1 stated that the information was correct and that the quiz questions in the middle were especially nice. MD

#1 also considered it of high pedagogic value. For constructive criticism, they stated that the wording of one sentence, while technically correct, could have been more precise. Instead of saying that technology is necessary since the pancreas is not functioning properly, the doctor advised that the application should state that Ludus needs to use insulin. Using technology is technically correct, as insulin is administered through technological tools, but insulin is essential, so it should be highlighted. MD #1 experienced some issues where the text was outside the speech bubble, which we concluded was caused by the abnormal screen aspect ratio on their mobile device.

Regarding module 2: Galactic Glucose, MD #1 stated that the game was really fun and a clever way to represent blood glucose management. For constructive criticism, they would like the blood glucose meter at the top to explicitly say which side is high or low, although they did correctly understand it. Otherwise, MD #1 found the game to be self-explanatory.

Feedback regarding module 3: Høyt eller Lavt was extremely positive. Again, MD #1 called it of very high pedagogic value. The only constructive criticism provided was to have more pictures, although that was quickly followed up by explaining that they knew it was a proof-of-concept.

Feedback regarding module 4: Pack the Bag, was also positive. The tips displayed when clicking the items were considered very useful. For constructive criticism, MD #1 would like to see more options to make it more difficult. They also recommended adding glucose tablets and a doctor's note regarding their disease, which are necessary when traveling to be able to bring their insulin and insulin pens through security in airports.

Medical Doctor #2

MD #2 also confirmed that the information in the app was medically correct.

Regarding module 1: Introduction, MD #2 also found it to provide useful information. MD #2 did not experience any visual issues.

Regarding module 2: Galactic Glucose, MD #2 thought the game was very entertaining and played it until they achieved all three stars. They were a bit confused at first about the controls but quickly learned on their own.

Regarding module 3: Høyt eller Lavt, they only gave it praise for being a useful tool for learning carbohydrates but also wished there were more pictures included.

Regarding module 4: MD #2 was positive to the concept, but would also like to see more "red herrings" in the game, i.e., items you do not need to bring.

7.8 Summary

This chapter has described the findings and results of the project. The literature review found important design factors when developing an application for young children with type 1 diabetes, necessary medical knowledge for the target group, and game mechanics to motivate the target group to use systems. The interview with the medical doctor provided information about the necessary medical knowledge to teach a newly diagnosed child with type 1 diabetes. We have presented the resulting application, along with its evaluation. Medical doctors assessed the medical information it contains as medically accurate, we have shown that it is effective at transferring knowledge to the user, and members of the target group deemed the application's usability as good.

8 Discussion

This chapter discusses various design choices made for the system, the results of the evaluation process, and the methods used. The chapter also discusses how the solution meets the requirements set for the task and future work that can be done to the prototype to turn it into a viable healthcare tool.

8.1 Design Choices

Some design choices were made to implement the system that deviated from the initial design. These design choices were made as more knowledge of the Unity game engine was gained and feedback during internal testing.

8.1.1 Mock-ups & Final Product

The first model mock-ups used a portrait orientation, also called vertical orientation, for the screen. This was changed in the final solution and later mock-ups, where a landscape orientation was used instead. The main reasoning behind this choice was how Unity manages phone orientation. If the prototype were to manage the phone's constantly changing orientation in the user's hand, the UI would also have to fit various aspect ratios. This adds complexity to the application, with a cost-benefit ratio deemed too high to pursue. While the main menu and settings would be okay with a portrait orientation, they look

just as good in landscape orientation, and the extra space ensures that the UI does not feel cluttered.

8.1.2 Galactic Glucose Controls

The initial design of level 2: Galactic Glucose featured a character that could be moved in the vertical plane by holding down a finger on the character and sliding it up and down. This design was changed to using two buttons to move it up and down instead. The choice was made for two reasons, the primary reason being game balance. Dragging the character up and down means that it can move extremely fast, which makes hitting the incoming foods way too easy unless an equal increase in the speed of the food compensates for it. Increasing the speed of the food would ensure that the game was still challenging, but the food would have to go so fast that the main limiting factor for a player would be how fast they can move the character up and down. This would also not leave any time to consider which food items to shoot and which to let pass through. The secondary reason was the complexity of the script required to drag the object up and down. While the script required for this was relatively easy to write, it was more complex than the buttons. More complex code means the solution is less readable if someone wants to continue the project in the future. As the buttons were better for game balance and less complex in design, it was a clear choice between the two options.

8.2 Knowledge Transfer Assessment

The results of the knowledge transfer assessment show that the application effectively teaches users about type 1 diabetes. The mean increase in knowledge based on the questionnaire was 38.0%, with a mean score of 55.5% before testing the application and 93.5% after testing the application. 50% of the participants got everything right on the second try.

It is worth noting that the testing between the tests only consisted of playing the game once for a few minutes. Further, replays and repetition are likely to increase the score. Furthermore, two of the users, who reported their knowledge of type 1 diabetes as poor prior to participating, scored 78% on their first try. This is a high score that drastically increases the mean value before testing, lowering the increase in the mean score after testing.

8.3 Research Group Feedback

The suggestion to increase the size of the blood glucose level bar at the top of the galactic glucose game is a valid suggestion. The focus of the game is to manage this bar, so it should also be a point of focus in the user interface. However, the suggestion of making the entire bar the background is not a good idea. An important part of game design is ensuring that the levels are aesthetic. While this is a prototype and certainly could improve its user interface and aesthetics in various parts of the app, the background for that game was chosen meticulously. The background is a kitchen due to the topic of the game being centered around food. The colors of the kitchen are also a mix of blue and pink, but it is not weighted in any direction. This ensures that the aesthetic is both dynamic and pleasing while also making it relatable to every user, no matter their gender or preference. The background can be seen in Figure 6.6. Using the bar as a background would not only make the game look less appealing but could end up being very confusing unless the design was extremely simplified.

The point about the use of text being difficult for the youngest children is valid. We were unfortunately not able to test the application on users younger than nine, so we could not assess whether this is indeed the case or not. However, we assume that younger children who struggle with reading might rate the application low in usability. We will discuss ways to mitigate this problem further in this chapter and the next chapter.

The application's user interface is most likely not responsive enough in terms of visual feedback. One example of this is the quiz in the introductory module. The character lets the user know whether the answer is correct or not, but it would be a good idea to implement additional graphical feedback to the user, such as animations or flashing colors based on their answer. For example, a correct answer could make the speech bubble light up with green, while an incorrect answer could use red.

There were some disagreements in the research group regarding the game design of shooting insulin toward the food. One researcher meant it was more intuitive that the user should just attempt to dodge the food instead of shooting it down. Another researcher stated their disagreement with this opinion, and the author disagrees as well. Shooting down the food is an integral part of the core gameplay loop and is what makes it fun. It is also fairly intuitive that it is not meant to be taken literally that insulin is shot into the food, but instead represents the administering of insulin to counter the effects of carbohydrates. Such was also proved during internal testing with the author's parents, one of them a patient with type 1 diabetes, who correctly pointed out to the other parent:

"You don’t shoot the meat with insulin! Shoot the pasta!"

While they are a lot older than the target group, it still indicates that the design is intuitive enough that it a justified decision. However, the comment regarding food flying past the user being confusing is more valid. Further work might have to consider whether to make it more intuitive through the user interface or to re-design the game to increase blood glucose levels when the food hits the character instead of when it flies past it.

8.4 Usability

The final SUS score for the application was 69.7. From this score, we can derive the following statements to describe the assigned usability rating:

- The application is just below the rating "Good."
- The application is within the fully acceptable range but borders on the line of high marginal acceptability.
- The application’s usability can be rated as just barely achieving a C, but it’s on the border of a D.

See Figure 8.1 for a representation of grading based on SUS score, reprinted from Bangor, A. et al. [65].

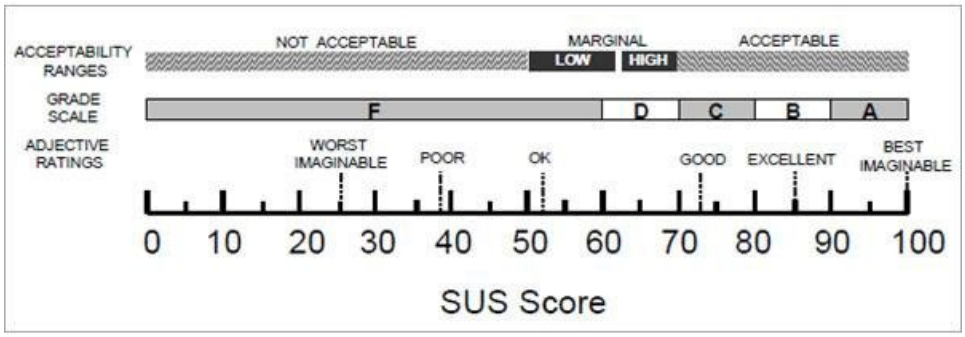

Figure 8.1: SUS scores grade rankings, reprinted from Bangor, A. et al. [65]

It is important to note that this evaluation’s low number of participants drastically affected the score. Three participants mean that each participant’s scoring immensely impacts the final score. In this case, the first and third participants

rated the application a 78, which is between "Good" and "Excellent," and statistically puts it in the top 15th percentile of applications in the world [65]. However, the second participant scored 53, which is barely acceptable. The mean score rounded up to the nearest integer was 70, which puts it in the top 40th percentile.

It is difficult to draw any solid conclusion with the number of participants. Brooke, J [66] shows that SUS is an effective method for evaluating usability with a low participation count but states that a minimum of 8 participants is desirable to draw confident conclusions. However, all participants evaluated the application's usability at an acceptable level, and 2/3 participants rated it in the top 15th percentile, which is a fairly high score.

It is worth mentioning that the SUS evaluation is designed for production-ready products, while this is a prototype. An acceptable score for the prototype created within a short period suggests that future work could easily result in an improved score.

It was desirable to compare the final achieved score to other applications utilizing the SUS evaluation method as well. The master's theses chosen for the comparison were also educational games where the authors had at least one supervisor in common with the author of this project. Stellander, M. [67] and Haugland, V. [68] both developed applications designed to encourage physical activity in users with intellectual disabilities. Stellander's application received a score of 61, and Haugland received a score of 58.5. In comparison, DiaLudus' score of 70 is quite high.

The participants, aged 9 and 12, covered two-thirds of the target group, which was 6 to 12. Unfortunately, we can not draw any conclusions regarding the effect age has on usability in this situation, as the oldest participant gave an identical score to one of the younger participants. There were no participants to represent the youngest section of the target group aged 6-8, so future work should emphasize recruiting participants from this age group for further evaluation.

The administrators of both groups, who were contacted for approval before posting, were very positive and excited about the project, indicating that patients with type 1 diabetes are open to new technological solutions and happy to help if they think the solution has promise. One group only accepted new members if they were parents of type 1 diabetes. We did not get access to this group, and the administrator posted the advertisement on our behalf. The other group allowed the author to post the advertisement, and the post reached over 20 likes and received one comment. The average post on the group seems to receive 0-3 likes and a few comments, with some more popular votes receiving

up to 40 likes. This indicates that the advertisement was fairly well received and garnered sufficient attention.

Both administrators did ask if it was possible to test the application with an iOS device. The application was designed and implemented to be cross-platform, but Android was chosen as the testing platform due to the simplicity of the process. Testing the application on iOS was deemed not important enough for this project, but the choice was done before receiving this feedback. Future attempts should probably spend the extra time required to plan evaluation using iOS devices to ensure the highest number of participants possible. We also received a suggestion to contact the local diabetes association at the end of the project, which is a useful tip for future work.

8.5 Medical Doctor Evaluation

The results of the medical accuracy evaluation show that the information presented in the application is both correct and valuable. In addition, one of the medical doctors rated the games as 'of high pedagogic value.'

The medical doctors also provided minor constructive criticism, such as clarifying what was high or low on the blood glucose meter in galactic glucose and specifying in the introduction that the character needs to use insulin to manage their blood sugar instead of 'use technology.' While technology is used to administer insulin, the focus should be on the effect of the insulin. These changes were added to the solution after receiving the feedback.

8.6 Requirements

The implemented prototype fulfills all functional requirements. However, one requirement that was not fully met was **REQ5**: 'The user should be able to play a game that teaches them how physical activity affects their blood glucose levels.' The introduction game does provide some information on this topic, such as physical activity generally lowers blood glucose levels, and intense physical activity can increase it. However, the information is mentioned once, which is not sufficient to develop a proper understanding of the topic. See Section 8.10 for how this can be improved.

8.7 Research Problem

The main research problem described in Section 1.2 was:

How can we design a mobile game application to educate children with type 1 diabetes on their disease?

This report has answered this question by presenting the methods, requirements, and design choices made, along with presenting a fully functional mobile application that meets the requirements set and has received positive feedback from the evaluation process.

8.7.1 Sub-problems

The research problem was divided into further sub-problems:

RP1: What factors are the most important to consider when developing a gamified educational mobile application for children with type 1 diabetes?

While it is difficult to conclude precisely what factors are the most important to consider, we can discuss the project's findings and provide suggestions based on them.

An important aspect of developing games for children is ensuring they are simple to use, easy to learn, and entertaining. Children today are bombarded with choices regarding their entertainment, so any application must emphasize removing any barriers to entry to the application, as those can be enough for the user to choose something else instead. One way to do this that we present is through the use of mini-games. By designing the application to contain multiple smaller games instead of a single large, complex game, it becomes easy for the user to pick it up and try the various games. This design also gives the user choice in what to do, which can help if they get bored quickly.

Developing an application for children poses great difficulties in the development of a user interface, as relying on a text-based approach might not be sufficient if the user is too young to read. The option of text-to-speech should most likely be part of the design for any application that attempts to transfer significant amounts of knowledge to younger children.

Another factor to consider is using the correct terminology. One such example is avoiding calling patients with type 1 diabetes 'diabetics'. The American Diabetes Association emphasized encouraged healthcare professionals to avoid this term,

as patients with type 1 diabetes are not to be defined by their disease.

The next factor is also tied to the third sub-problem.

RP3: Which techniques and tools can be used to increase motivation in children to use educational games?

Motivation is also one of the most important factors to use. This project's solution was to use a combination of receiving up to three stars per level based on performance. This provides visual feedback and progress while also motivating the user to achieve all three stars on every level, as it can be mildly frustrating in a motivational way to see that you are missing a few stars. Another feature we used to increase motivation was the use of unlockable cosmetics for the Ludus character in the app. The user can change the character's color (e.g., blue, red, green) from the beginning, but performing well unlocks other cosmetics that change the character's shape or add clothing. These unique looks make the user curious about what else they can unlock, which motivates them to play, but also leads to the third technique; customizability.

It is vital to allow the user to customize their experience and make it personal. By allowing the user to change the cosmetics of the user to fit their tastes, the user will feel more tied to the game and be more motivated to play. An important factor to consider when making the application customizable is to ensure that the character or avatar in the game is something every user can relate to. This can be achieved by allowing extremely detailed customization, where the user can pick every aspect of their avatar's appearance or through a standard avatar that is relatable to everyone, regardless of age or gender. DiaLudus takes the latter approach by using a cute, endearing slime monster.

RP2: What knowledge should the application educate its users on? In this report, we have described the most important knowledge a child should learn after being diagnosed with type 1 diabetes. The findings are based on the expert opinion of the interviewed medical doctor and existing related work. The necessary knowledge is described in Chapter 7.

8.8 Limitations

8.8.1 Evaluation

It is important to acknowledge the low number of participants in the evaluation of the prototype, as it can allow inherent biases in individuals to have a more significant effect on the results than is desired.

Recruiting participants from the target group to evaluate the usability of the application was a major challenge of this project. The target group is a very small subset of the Norwegian population, so getting into contact and raising enough interest to make the effort required to participate worthwhile is difficult. While three participants is a low number of participants, it is actually a surprisingly high number when compared to previous similar projects. Makhlysheva, A developed a serious game titled 'DiaSpill' [69] for children with type 1 diabetes and attempted to recruit participants from Tromsø county. Their findings were that there were only 18 potential participants in the area. A nurse contacted all 18 potential candidates, but only one person responded and participated in the evaluation of the application. We decided that reaching out to established Facebook groups would result in better reach, which proved to be true, as we were able to recruit three participants.

The six participants in the knowledge transfer assessment are not optimal either, but the number is high enough to where it has enough significance to draw a conclusion from it. The only downside to the number of participants is that each individual has a lot of impact on the mean results.

The knowledge transfer assessment was not performed on the target group. The reasoning behind this was that the majority of the target group has been living with the diagnosis for years and has a fairly high understanding of type 1 diabetes and self-management. Testing the application, which for this project was intended to contain basic knowledge about diabetes, with this user group would most likely result in the users getting everything right on the first attempt, therefore making it impossible to evaluate if the application is efficient at teaching its intended learning material. The optimal participants for this group would have been patients newly diagnosed with type 1 diabetes, but not attempting to recruit them was an intentional decision. Children who have recently received such a diagnosis, and their parents, have a lot to learn and adapt to in this crucial phase. Attempting to recruit these patients would provide them with extra work that they might not have time for, and any nudging from the author could be perceived as fairly stressful. It is also a group that is difficult to recruit, as was further discussed in Section 8.4.

Another alternative would be to perform the assessment with participants in the same age group but with no diagnosis of type 1 diabetes. This approach might have provided more accurate results as to how effective the application is for educating children on the topic. However, involving children in an assessment like this poses several challenges. There are additional privacy concerns whenever children are involved, as explained in Section 3.7. An application to Sikt would be mandatory, which takes at least a month to get feedback on. Recruitment would also have to be done, including approval from the parents of any participants, as the children are not old enough to give such approval

on their own. These challenges, along with the time constraint of a master's thesis performed in one semester, led to the decision to recruit students with self-reported low understanding of type 1 diabetes. This group would be easy to contact and require no additional privacy concerns. We also deemed that the results gained from this group would be representative enough for all ages as to if the application was effective at transferring knowledge.

The participant number does not affect the evaluation of the medical accuracy. Both participants are subject field experts and, therefore, qualified to assess if the application's information is medically accurate.

8.9 Known Bugs

Some bugs that were detected or reported at the end-stage of testing were not fixed, either due to time constraints or the inability to reproduce the reported bug.

One tester reported that the first level would get stuck on the initial dialogue after playing through it once. Subsequent attempts at starting level one would lead to the same problem. The author could not reproduce this error on any device, and the other test participants did not report it. The tester reported that their device ran on Android version 8, which is extremely outdated. For reference, the test device used for this project ran on Android 13. The author and tester concluded that the device's outdated firmware was the cause of the error, but the cause is not confirmed.

At one point, the medical doctor experienced the text appearing outside the speech bubble in level 1. The author could not replicate this bug on any of the test devices. Further questioning revealed that the old phone the doctor was using to test it had a very wide screen relative to its length. This could mean the aspect ratio differed too much from the reference resolution used to develop the user interface.

8.10 Future Work

The presented solution was implemented in a short time period as a prototype or proof-of-concept. Therefore, there are naturally improvements that can be made to enhance the application. This section will present possible improvements that can be made if someone continues on the project.

8.10.1 Text-to-Speech

One important feedback from the research group was that the reading skills of the youngest users might not be sufficient to understand the game properly. While this game might be another opportunity to practice their reading, it could also hamper their motivation to use the application. Implementing a text-to-speech (TTS) system that reads the text to the user is a good idea. This should also be something you can disable in the settings menu if desired.

8.10.2 Difficulty Setting

The difference in cognitive abilities between children aged six and 12 is significant. This makes it challenging to design a system that is simple enough for the younger end of the users but also stimulating for the older group. One solution to this problem is to implement a setting the user can change based on their age that affects things like game difficulty and language used in the application.

8.10.3 Expand The Games

Future development based on the prototype should contain a game that teaches the user about the more practical aspects of blood glucose management. One way to do this would be similar to the Rufus game mentioned in Section 2.4 where the user could measure the blood glucose levels of the Ludus character through various technologies, such as the older finger-prick method or a CGM. The user should then be prompted with various tools to regulate blood glucose levels and receive feedback based on their choice. These tools could include an insulin pen, an insulin pump, various food items, or physical activity.

A separate game should focus on the relationship between physical activity and blood glucose levels. One way to do this could be to develop a 'Temple Run' [70] inspired game, where the character must escape from something by running through a course with obstacles. Their blood glucose levels should constantly lower as they keep on running. However, at specific points, they might have to switch to some form of intense physical activity that causes adrenaline release, which increases blood glucose levels.

8.11 Summary

This chapter has discussed the design choices made in the development of the DiaLudus application, how the application has met every requirement set for the project, two known bugs, and the results of the evaluation process. Medical doctors' evaluations proved that the information presented in the application is medically accurate. The knowledge transfer assessment performed on students showed that the application successfully and effectively teaches the user the information it contains. Usability evaluation, although performed by only three participants, was performed by the target group and showed that the application has a satisfactory user interface, although there is room for improvement. Future work should aim to provide TTS support to ensure the youngest users understand everything in the application and difficulty setting to account for users' different ages and cognitive abilities, expand the existing games and add more mini-games.

9

Conclusion

This thesis has described the process and findings of developing an educational gamified application with mini-games for children with type 1 diabetes aged 6-12. The requirements and design of the application are based on the knowledge obtained from the literature review, related publicly available commercial solutions, an interview with a medical doctor working with the target group, and the author's personal experience with type 1 diabetes. The resulting prototype application lays the groundwork for further development of a commercially available educational tool for the healthcare sector.

The resulting solution of this project is a cross-platform mobile application that utilizes a collection of educational mini-games to educate children on various topics regarding type 1 diabetes and self-management of the disease. The application teaches kids about the physiology and anatomy of type 1 diabetes, blood glucose level management, how insulin and carbohydrates affect blood glucose levels, and the impact of physical activity. The solution has also been implemented to easily enable future extensions of the games, such as more games or more content in existing games. The application is also safe to use and ensures privacy to the user, as the only data it stores is related to progress within the game.

The solution application has been evaluated using multiple methods. Medical doctors have evaluated and confirmed the accuracy of the medical information provided in the games, and a knowledge transfer assessment has shown that the application is effective at teaching users the information it contains.

Most importantly, the application has been evaluated by the target group it is intended for, who deemed its usability satisfactory.

Future work on this project should expand the gameplay already in the application and provide more games for the user. More learning should be added regarding how physical activity affects blood glucose levels. Steps should also be taken to ensure that the user interface is improved so that the usability rating is increased. Further evaluation of the usability should also contain a larger group from the target audience, and the evaluation process should also be performed on iOS devices in addition to Android.

9.1 Contribution

The contribution of this thesis is the description of how to produce an educational mobile application for children with type 1 diabetes. The report describes important factors to consider when developing it, such as what knowledge it is required to educate on, but also what should be prioritized, and how to increase the users' motivation to use the application.

The application's design is based on the relevant literature and already available technological solutions but presents a novel approach by using multiple smaller games called mini-games. This approach allows the developers to fit more knowledge into the application in bite-size pieces, reduces the complexity of game design compared to larger games, makes it easier for the user to pick it up and start playing, and makes it easy for the developer to expand it further.

This project has also contributed to the argument that educational games are a viable solution for the healthcare sector, specifically for the treatment of newly diagnosed patients with type 1 diabetes, through increasing their knowledge early, which is proven to improve their prognosis. Both healthcare workers, older patients with diabetes, the target group, and the target group's parents have shown great excitement about the project, which proves that it is a project worth further work in the future.

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A

Interview Consent Form

Vil du delta i forskningsprosjektet

A mobile system for managing type 1 diabetes in children

Dette er et spørsmål til deg om å delta i et forskningsprosjekt hvor formålet er å utforske, utvikle, og teste en mobilapplikasjon for å hjelpe barn nylig diagnosert med diabetes type 1. I dette skrivet gir vi deg informasjon om målene for prosjektet og hva deltakelse vil innebære for deg.

Formål
Formålet med prosjektet er å utforske hvordan mobilspill kan benyttes til opplæring av barn nylig diagnosert med type 1 diabetes. For å oppnå dette skal det utføres et litteratursøk for å se hva faglitteratur indikerer. Det er også ønskelig å få innspill fra helsetjenesten gjennom intervju med helsepersonell. Deretter skal en applikasjon utvikles og testes hvis det lar seg gjøre.

Prosjektet er en Masteroppgave ved UiT Arctic University of Norway.

Hvem er ansvarlig for forskningsprosjektet?
Fakultetet for naturvitenskap og teknologi, institutt for informatikk ved UiT Arctic University of Norway er ansvarlig for prosjektet.

Hvorfor får du spørsmål om å delta?
Du får spørsmål om å delta etter en telefonsamtale med barne- og ungdomsavdelingen ved UNN.

Hva innebærer det for deg å delta?
Hvis du velger å delta i prosjektet, innebærer det at du deltar i et semi-strukturert intervju. Det vil ta deg ca 15-30 minutter. Intervjuet vil inneholde spørsmål angående hvilken informasjon som barnet bør få opplæring i etter nylig diagnose. Det vil tas lydopptak og notater under intervjuet.

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

- Prosjektgruppen vil være de eneste med tilgang til lydopptaket (student og veiledere).
- Endelig rapport vil leveres inn som en oppgave til Universitetet.
- Ditt navn vil ikke nevnes i sluttrapporten og vil bli byttet ut med en kode, for eksempel «helsepersonell 1»

Hva skjer med personopplysningene dine når forskningsprosjektet avsluttes?
Prosjektet vil etter planen avsluttes når oppgaven blir levert, 1. Juni 2023. Etter prosjektslutt vil lydopptak bli slettet.

Hva gir oss rett til å behandle personopplysninger om deg? Vi behandler opplysninger om deg basert på ditt samtykke.

På oppdrag fra Institutt for Informatikk ved UiT Arctic University of Norway har Personverntjenester 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, og å få utlevert en kopi av opplysningene
- å få rettet opplysninger om deg som er feil eller misvisende
- å få slettet personopplysninger om deg
- å sende klage til Datatilsynet om behandlingen av dine personopplysninger

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

- Institutt for Informatikk ved UiT Arctic University of Norway.
  - *Eirik Årsand, eirik.arsand@uit.no, +4777644760 (Hovedveileder)*
  - *Sigurd Johannes Brattland, sbr091@uit.no, +47 (Student)*
- Vårt personvernombud: Joakim Bakkevold, personvernombud@uit.no

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

- Personverntjenester på epost (personverntjenester@sikt.no) eller på telefon: 53 21 15 00.

Med vennlig hilsen

(Veileder) (Student)

Samtykkeerklæring

Jeg har mottatt og forstått informasjon om prosjektet *[sett inn tittel]*, og har fått anledning til å stille spørsmål. Jeg samtykker til:

☐ å delta i *intervju*

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

---------- (Signert av prosjektdeltaker, dato)

B

Knowledge Questionnaire

Kunnskapstest Type 1 Diabetes

Hei!

Skjemaet inneholder noen få enkle spørsmål angående type 1 diabetes.
Du vil ikke få vite om svaret ditt er riktig eller feil.
Testen skal gjøres to ganger:

1. Uten å ha testet applikasjonen
2. Etter å ha testet applikasjonen

Svarene vil så bli sammenlignet for å se om brukeren har lært noe fra applikasjonen.

Spørsmålene er anonyme, men du vil få en kode som brukes til å knytte dine to svar sammen.
Det vil ikke være noen måte å knytte deg til koden du har fått tildelt, og denne er helt tilfeldig.

* Indicates required question

1. Vennligst oppgi koden du mottok *

2. Hva forårsaker type 1 diabetes? *

Check all that apply.

- [ ] Usunn livstil, for mye sukker/søtsaker og lite aktivitet
- [ ] Nyresvikt fører til svak hormonproduksjon
- [ ] Auto-immun respons skader bukspyttkjertelen
- [ ] Vi vet egentlig ikke med 100% sikkerhet

3. Hvilket hormon er nødvendig for at cellene skal kunne utnytte glukosen i blodet *

Mark only one oval.

- Adrenalin
- Insulin
- Kolesterol
- Testosteron

Untitled Section

4. Hvilket organ er ansvarlig for produksjonen av insulin? *

Mark only one oval.

- Bukspyttkjertelen
- Leveren
- Nyrene
- Tynntarmen

5. Hvilken effekt på blodsukkeret har inntak av karbohydrater? *

Mark only one oval.

- Karbohydrater øker blodsukkeret
- Karbohydrater senker blodsukkeret

6. Hvilken effekt på blodsukkeret har inntak av insulin? *

Mark only one oval.

- Insulin senker blodsukkeret
- Insulin øker blodsukkeret

7. Hvilke av disse matvaregruppene inneholder mye karbohydrater? *

Check all that apply.

- [ ] Kjøtt
- [ ] Brød
- [ ] Pasta
- [ ] Salat
- [ ] Kake

Fjelltur

Du skal på en lengre tur, for eksempel på fjellet, og pakker sekken din. De neste spørsmålene vil be deg huke av utstyr du mener er viktig for en diabetiker å ta med seg.

8. Hva bør en type 1 diabetiker ha med seg på vanlig fjelltur? *

Check all that apply.

- [ ] Karbohydrater (solbærsaft, juice, sjokolade-/energibar)
- [ ] Protein (kjøtt, proteindrikke etc)
- [ ] CGM og pumpe
- [ ] Melk
- [ ] Vanlig blodsukkermåler og insulinpenn (backup)
- [ ] Vann
- [ ] Batteri til pumpe
- [ ] Ekstra insulin
- [ ] Telefon

9. Det er veldig varmt denne dagen. Hva mer bør de huske å ta med seg? *

Mark only one oval.

- ◯ Kjølebag
- ◯ Varmebag

/C

SUS Questionnaire

Evaluering av DiaLudus

Side 1

Obligatoriske felter er merket med stjerne *

Hei!
Hvis du har åpnet dette skjemaet har du mest sannsynlig blitt invitert til å delta i et mastergradsprosjekt ved UiT.

Sørg for at du har mottat, lest og fortstått tilhørende samtykkeskjema før du besvarer dette spørreskjemaet. Samtykkeskjema og installasjonsfil til appen finner du ved å trykke på denne Google Drive lenken.

Før du besvarer skjemaet ber vi om at du tester applikasjonen.

Installasjon må gjøres på en mobil med Android som operativsystem.

Installasjonsveiledning:

Obs! Fungerer kun på Android-mobiler.

Sørg for at mobilen din kan installere applikasjoner som ikke kommer fra Google Play:

1. Åpne "innstillinger"/"settings"
2. Velg "Apps"/"Apper"
3. Velg "Special app access"/"Spesiell Apptilgang" (eller "Advanced"/"Avansert"-> "Special App Access"/"Spesiell Apptilgang"
4. Velg "Install Unknown Apps" / "Installer ukjente apper" eller lignende
5. Gi tilgang til dette for:
    1. File management / Filer
    2. Chrome eller annen nettleser

NB! Metode for dette kan variere fra modell til modell. Hvis det blir vanskelig kan jeg anbefale å søke "hvordan installere apk på android". Her er en nyttig ressurs på norsk: Guide

Etterpå er det bare å trykke på ikonet til appen, så vil den spørre om tillatelse til å installere og du er så klar til å teste!

Annen informasjon

Vi ønsker at ditt svar skal være så anonymt som mulig og ber derfor at du ikke oppgir identifiserende informasjon.

Vi er også klare over at informasjonen i applikasjonen kan være simpel for de fleste med erfaring angående diabetes, og er kun ute etter tilbakemelding på brukervennlighet.

På forhånd takk for du valgte å delta i dette prosjektet. Vi setter veldig stor pris på det!

Ved å svare på dette skjemaet bekrefter du at du har lest og forstatt all oppgitt informasjon og samtykker til at svaret ditt kan brukes i prosjektet.

Sideskift

Side 2

Obligatoriske felter er merket med stjerne *

Hei! Du vil snart bli presentert 10 påstander om applikasjonen du har testet. Din jobb er å svare hvor mye du er enig eller uenig med disse påstandene på en skala fra 1-5 (1 betyr veldig uenig og 5 betyr veldig enig).

Vi ber om at du svarer din umiddelbare reaksjon til spørsmålet, så ikke tenk for lenge over svaret. Hvis du er usikker er det anbefalt at du svarer i midten (3).

Takk igjen for at du ville delta!

Hvor mange timer brukte du applikasjonen?

Oppgi ca. antall timer du brukte på å teste applikasjonen

Hvor gammel er du?

Sideskift

Side 3

Obligatoriske felter er merket med stjerne *

Jeg tror appen kan bli brukt jevnlig av nydiagnoserte barn med type 1 diabetes *

Veldig uenig **Veldig enig**

1 **2** **3** **4** **5**

Verdi

Jeg syntes applikasjonen var unødvendig kompleks *

Veldig uenig **Veldig enig**

1 **2** **3** **4** **5**

Verdi

Jeg syntes applikasjonen var lett å bruke *

Veldig uenig **Veldig enig**

1 2 3 4 5

Verdi

Jeg tror jeg ville trengt hjelp av noen med teknisk kompetanse for å kunne bruke denne applikasjonen *

Veldig uenig **Veldig enig**

1 2 3 4 5

Verdi

Jeg syntes den forskjellige funksjonaliteten i applikasjonen er godt integrerte *

Veldig uenig **Veldig enig**

1 2 3 4 5

Verdi

Jeg syntes det var for mye inkonsistens i applikasjonen *

Veldig uenig Veldig enig

1 2 3 4 5

Verdi

Jeg tror de fleste ville raskt lært hvordan man bruker applikasjonen *

Veldig uenig Veldig enig

1 2 3 4 5

Verdi

Jeg syntes at systemet var upraktisk å bruke *

Veldig uenig Veldig enig

1 2 3 4 5

Verdi

Jeg følte meg veldig selvsikker når jeg brukte applikasjonen *

Veldig uenig Veldig enig

1 2 3 4 5

Verdi

Jeg måtte lære meg mye før jeg kunne komme i gang med applikasjonen *

Veldig uenig				Veldig enig
1	2	3	4	5

Verdi

Sideskift

Nettskjema

VILKÅR

Personvern og vilkår for bruk
Nettskjema bruker informasjonskapsler
Tilgjengelighetserklæring

HJELP OG KONTAKT

Veiledning for Nettskjema
Kontaktinformasjon

NETTSKJEMA ER UTVIKLET OG DESIGNET AV

Universitetet i Oslo

/D

Evaluation Consent Form

Vil du delta i forskningsprosjektet

A mobile system for managing type 1 diabetes in children

Dette er et spørsmål til deg om å delta i et forskningsprosjekt hvor formålet er å utforske, utvikle, og teste en mobilapplikasjon for å hjelpe barn nylig diagnosert med diabetes type 1. I dette skrivet gir vi deg informasjon om målene for prosjektet og hva deltakelse vil innebære for deg.

Formål
Formålet med prosjektet er å utforske hvordan mobilspill kan benyttes til opplæring av barn nylig diagnosert med type 1 diabetes. For å oppnå dette skal det utføres et litteratursøk for å se hva faglitteratur indikerer. Det er også ønskelig å få innspill fra helsetjenesten gjennom intervju med helsepersonell. Deretter skal en applikasjon utvikles og testes hvis det lar seg gjøre.

Prosjektet er en Masteroppgave ved UiT Arctic University of Norway.

Hvem er ansvarlig for forskningsprosjektet?
Fakultetet for naturvitenskap og teknologi, institutt for informatikk ved UiT Arctic University of Norway er ansvarlig for prosjektet.

Hvorfor får du spørsmål om å delta?
Du får spørsmål om å delta fordi du dekker et av følgende kriterier:

- Du har type 1 diabetes
- Du er foresatt eller bekjent av noen med type 1 diabetes

Hva innebærer det for deg å delta?
Hvis du velger å delta i prosjektet, innebærer det at du tester ut en prototype-applikasjon for opplæring om type 1 diabetes. Prototypen vil inneholde noen mobilspill. Etterpå vil du kunne gi tilbakemelding om prototypen via et spørreskjema.

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

- Prosjektgruppen vil være de eneste med tilgang til spørreskjema (student og veiledere).
- Endelig rapport vil leveres inn som en masteroppgave til Universitetet.
- Ditt navn vil ikke nevnes i sluttrapporten og vil bli byttet ut med en kode, for eksempel «bruker 1»

Hva skjer med personopplysningene dine når forskningsprosjektet avsluttes?
Prosjektet vil etter planen avsluttes når oppgaven blir levert, 1. Juni 2023. Etter prosjektslutt vil spørreskjema bli slettet.

Hva gir oss rett til å behandle personopplysninger om deg? Vi behandler opplysninger om deg basert på ditt samtykke.

På oppdrag fra Institutt for Informatikk ved UiT Arctic University of Norway har Personverntjenester 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, og å få utlevert en kopi av opplysningene
- å få rettet opplysninger om deg som er feil eller misvisende
- å få slettet personopplysninger om deg
- å sende klage til Datatilsynet om behandlingen av dine personopplysninger

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

- Institutt for Informatikk ved UiT Arctic University of Norway.
  - *Eirik Årsand, eirik.arsand@uit.no, +4777644760 (Hovedveileder)*
  - *Sigurd Johannes Brattland, sbr091@uit.no,+47 (Student)*
- Vårt fungerende personvernombud: Sølvi Brendeford Anderssen, personvernombud@uit.no

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

- Personverntjenester på epost (personverntjenester@sikt.no) eller på telefon: 53 21 15 00.

Med vennlig hilsen

(Veileder)

Samtykkeerklæring

Jeg har mottatt og forstått informasjon om prosjektet *DiaLudus* og har fått anledning til å stille spørsmål.

Jeg samtykker til at mine eller mitt barns opplysninger behandles frem til prosjektet er avsluttet

---------- (Signert av prosjektdeltaker, dato)

/E

E-mails

E.1 E-mail conversation DPO

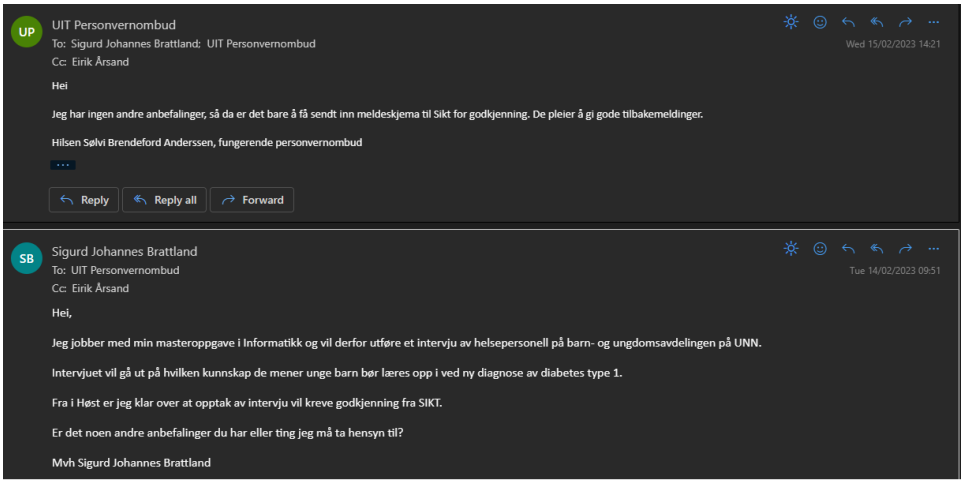

Figure E.1: E-mail conversation with functioning DPO at UiT regarding interview with healthcare workers

Figure E.2: E-mail conversation with functioning DPO at UiT regarding evaluation of application by the target group