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Tom Schrier

## uniLeague

Measuring student engagement in IDG2100 at  
NTNU in Gjøvik

Bachelor's thesis in Bachelor Web Development

Supervisor: Gioele Barabucci

May 2022



Norwegian University of  
Science and Technology



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Faculty of Architecture and Design  
Department of Design



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## Foreword

This thesis is our bachelor thesis in web development at NTNU in Gjøvik. The thesis explores how our web application, uniLeague, is used to summarize Kahoot!-quizzes and affects students' engagement. We have worked steadily on the project and have had a great collaboration within the group. We want to take this opportunity to thank our tutor, Gioele Barabucci, for good cooperation and good guidance during the project period. We also want to thank our product owner, Carlos Vicent-Monllao, who let us use his lectures to study the effect of our application. Lastly, we also want to thank all students from BWU20 who took the time to help us answer our survey and participate in our user testing.

May 13<sup>th</sup>, 2022, Gjøvik.

Cornelius Ottar Sandmel

Olav Einar Skjerve

Tom Schrieber

## Abstract

**Title:** uniLeague – Measuring student engagement in IDG2100 at NTNU in Gjøvik

**Date:** 13.05.2022

**Participants:** Cornelius Ottar Sandmæl, Glenn Eirik Hansen, Tom Schrier

**Supervisor:** Gioele Barabucci

**Employer:** Department of Design (ID) at Norwegian University of Science and Technology in Gjøvik

**Subject:** Web development

**Keywords:** Web development, web application, engagement, design, development, sustainability

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This thesis analyzes if and how a full-stack web application displaying Kahoot!-quiz results engages students in the IDG2100 course at NTNU in Gjøvik. We designed and developed a single page application called “uniLeague” to answer these questions. We measured the engagement of 13 students in the course IDG2100 with the Student Course Engagement Questionnaire by Handelsman et al. Our results showed a slight increase in student engagement, consistent with other research that has found gamification to have a beneficial effect on student engagement. uniLeague is a promising beginning for increasing student engagement over a whole semester, academic course, or even a three-year program.

## Abstract (Norwegian)

**Tittel:** uniLeague – Measuring student engagement in IDG2100 at NTNU in Gjøvik

**Dato:** 13.05.2022

**Deltakere:** Cornelius Ottar Sandmæl, Glenn Eirik Hansen, Tom Schrier

**Veileder:** Gioele Barabucci

**Oppdragsgiver:** Department of Design (ID) at Norwegian University of Science and Technology in Gjøvik

**Fag:** Webutvikling

**Stikkord:** Web development, web application, engagement, design, development, sustainability

**Antall sider:** 117 + 47

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**Antall vedlegg:** 16

Denne oppgaven analyserer om en fullstack-nettapplikasjon som viser resultater fra Kahoot!-quizer engasjerer studenter i IDG2100-emnet ved NTNU i Gjøvik. For å besvare dette spørsmålet designet og utviklet vi en *Single Page Application* som vi kaller for «uniLeague». Vi målte engasjementet til 13 studenter i emnet IDG2100 med *Student Course Engagement Questionnaire* av Handelsman et al. Resultatene våre viste en liten økning i studentengasjement, i samsvar med annen forskning som har funnet at *gamification* har en gunstig effekt på studentengasjement. uniLeague er en lovende begynnelse for å øke studentengasjementet over et helt semester, akademisk kurs eller til og med et treårig studieprogram.

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# 1 Introduction

The main contribution of this thesis is a web application used to test if and how much gamification and visualization of quiz results help improve students' engagement in subjects taught at NTNU. We developed a MERN-based web application, quantified its effectiveness, and ensured it conformed to the United Nations' Sustainable Development Goal 13: Climate Action.

Gamification is a term that refers to the process of incorporating video game components into non-gaming systems to increase user engagement (Deterding et al., 2011). Games are ingrained in our daily lives, and gamification of education is not a new concept. When people complete tasks using strategies such as leaderboards and instant personalized feedback, they feel a greater sense of ownership and purpose (Flatla et al., 2011).

Today, NTNU incorporates gamification into its educational program. For example, associate professor Carlos Vicient-Monllaó, uses Kahoot!-quizzes to keep students engaged during lectures. The quizzes' results are displayed on a leaderboard, with the top five students receiving recognition for their efforts. A leaderboard is a table that compares the performance of one user to that of others (Christy and Fox, 2014; Höllig, Tumasjan, and Welpe, 2020).

Professor Vicient-Monllaó is looking for a tool that will automate calculating overall quiz results and creating a class leaderboard that currently requires human labor; we refer to him as our *product owner*. The product owner hopes that the leaderboard contributes to increased student engagement. Additionally, this leaderboard should be visible to students outside of lectures.

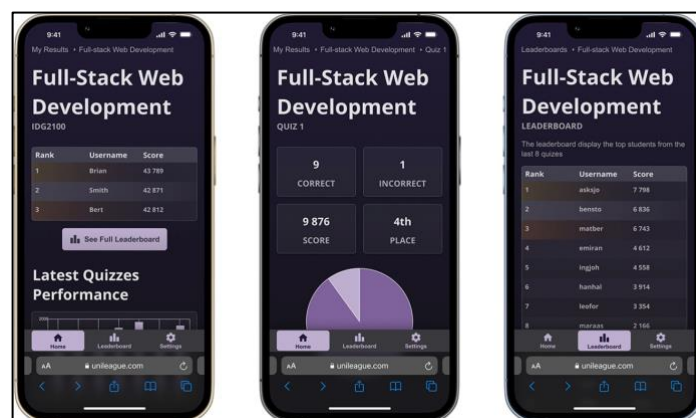


Figure 1. Preview of uniLeague

Our thesis will examine how we designed and developed "uniLeague," a web application that calculates and displays quiz results on a class leaderboard. Additionally, we examine the effect of uniLeague on student engagement in a compulsory web development course at

NTNU Gjøvik. Finally, it is critical to develop the web application sustainably to contribute to the United Nations' Sustainable Development Goal 13: Climate Action.

## 1.1 Presentation of today's solution

We will describe the current solution in greater detail to better understand the problem. At the end of a lecture, the lecturer presents to students an overall leaderboard with the top five students. Figure 2 shows that the current solution consists of an Excel sheet and a manual made leaderboard.

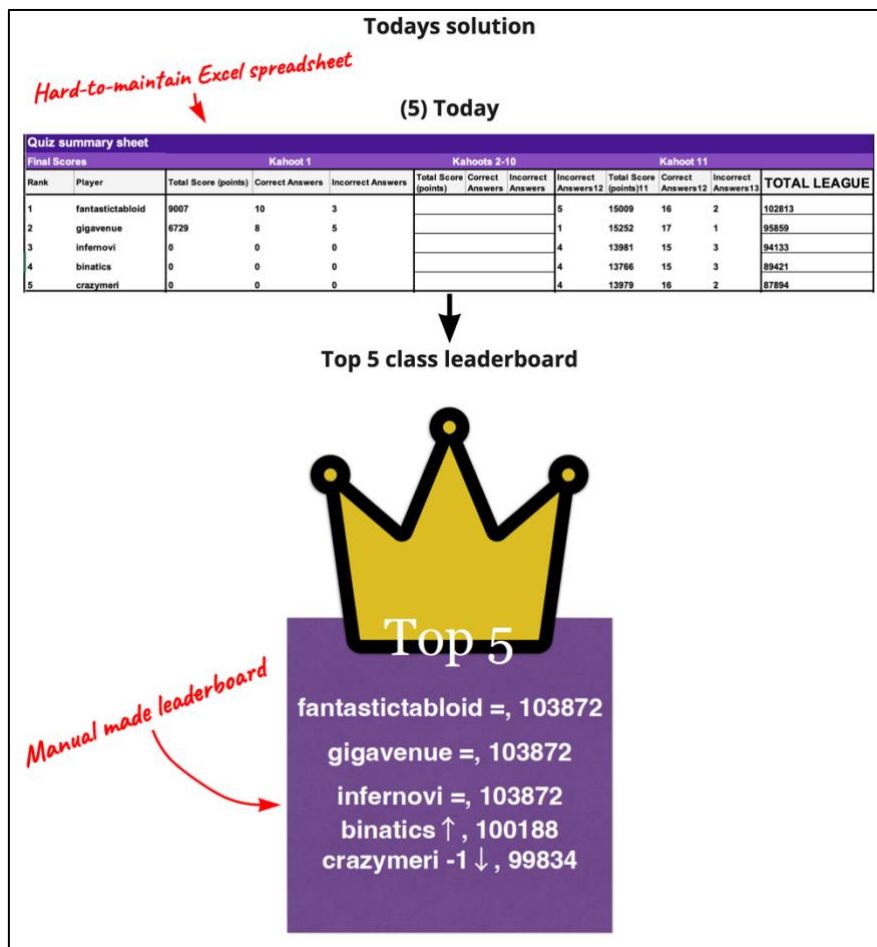


Figure 2. The current leaderboard. (Names have been anonymized as these could reveal personal information)

The project owner's current solution consists of eight steps, each time-consuming and requiring human labor. The steps are as follows:

1. Download Kahoot! quiz results
2. Open the .xlsx file
3. Copy all the results
4. Paste the results into the "main" Excel sheet



5. Alphabetize the usernames
6. Check if there are duplicate names
7. If there are duplicates -> a; otherwise -> b
  - a. Add the results for the duplicate username
  - b. Sort the Excel sheet in descending order by the score
8. Copy the top five students and paste them into the Keynote

Figure 3 illustrates the steps in a flowchart below.

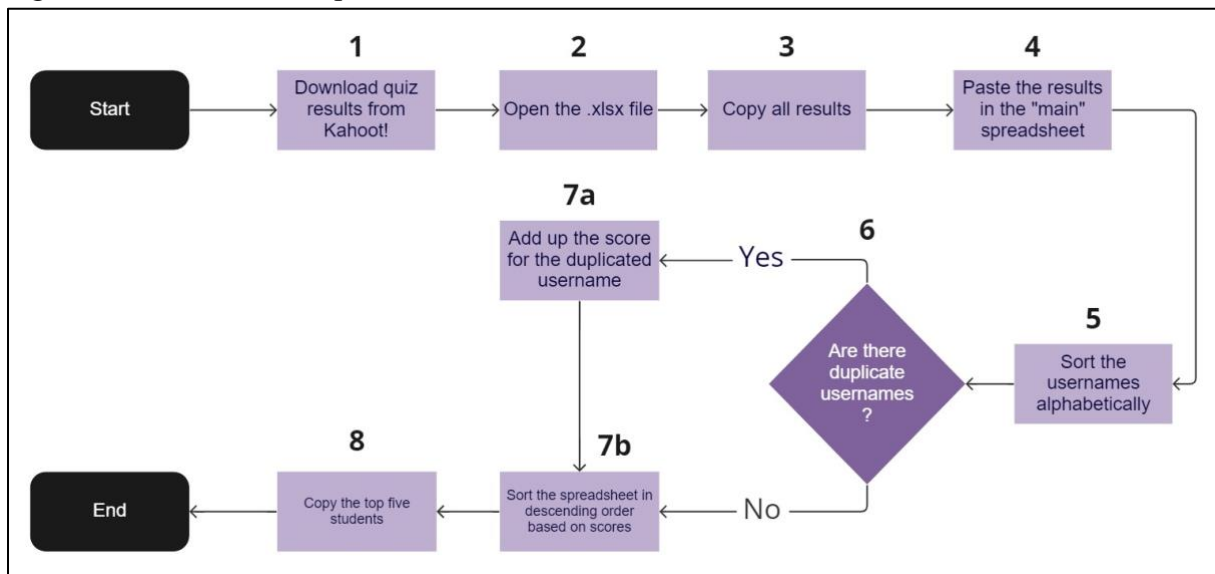


Figure 3. Flowchart describing the product owner's current workflow

This brings us to the desiderata.

## 1.2 Desiderata

The product owner outlined the ten specific desiderata during a meeting in September 2021 (see *Appendix 1: Introductory meeting with the product owner* on page 137). These were as follows:

1. Track students' progress through a semester
2. Graphical representation of quiz results
3. Display the students in the top five
4. Keep everyone outside the top five anonymous
5. Reduce human error
6. Give points for other in-class activities
7. Scale the number of users
8. Further develop functionality
9. Manage users

10. Let students share their results

The wishes can best be classified under five headings: *Track students and class progression* (1), *Visualization* (2, 3, 4), *Summarization of scores* (5), *Scalability* (6, 7, 8, 9), and lastly, *Sharing* (10).

### 1.2.1 Track students and class progression

The product owner's first and most critical feature is the ability to track their students' progress through a semester, year, or even a three-year study program.

### 1.2.2 Visualization

Second, after uploading the files to the web application, the product owner wishes the students to see their progress and position on the leaderboard. The product owner wishes to maintain the anonymity of everyone outside the top five positions on the leaderboard. The product owner hopes that anonymity will keep students motivated, even if students are near the bottom of the leaderboard.

### 1.2.3 Summarization of scores

Thirdly, one of the areas that present difficulties is the summarization of scores. Currently, this is accomplished manually by the product owner or a student assistant. As a result, the product owner wants this process to be automated, thus eliminating the possibility of human error.

### 1.2.4 Scalability

The following four wishes are that the product owner wishes the application to be scalable. "To be scalable" means they want to integrate activities besides Kahoot, like "lecture covers" and Mentimeter. The application should handle several hundred students, and the product owner should be able to add and remove users. The application should also be able to be further developed by the product owner.

### 1.2.5 Sharing

Lastly, the product owner wishes that the students could share their results with others.

In the end, all the features outlined above should be available for free.

## 1.3 Problem statement

We define the following problem statement to solve the product owner's desiderata.

*Does a web application displaying Kahoot!-quiz results engage students in the IDG2100 course at NTNU in Gjøvik?*

To help us answer the problem statement, we divided the question into three segments. We will discuss the design and development of the web application, the level of student engagement, and the importance of a sustainable web as we live in the twenty-first century. Consequently, our thesis comprises three distinct problem areas:

1. Design and develop the web application
2. Measure the engagement
3. Ensure sustainability

### 1.3.1 Definition of concepts in the problem statement

The following section defines essential concepts found in the problem statement given above.

#### 1.3.1.1 *Web application*

This thesis defines a *web application* as a program released via the Internet and accessible by end-users via a standard web browser.

#### 1.3.1.2 *Kahoot*

*Kahoot!* is a gamification-based learning platform that schools and other educational institutions utilize (Kahoot!, n.d.). Its multiple-choice quizzes, dubbed "kahoots," are created by users (often teachers and professors) that players can view in a web browser or the "Kahoot" app.

#### 1.3.1.3 *IDG2100*

The course code for "Full-Stack Web Development" at NTNU Gjøvik is *IDG2100*. By *IDG2100*, we mean the Full-Stack Web Development course held in the spring semester of 2022 (20 weeks).

#### 1.3.1.4 *Sustainable web design*

We will use the definition given by Tom Greenwood in his book *Sustainable Web Design*: "Sustainable web design is an approach to designing web services that prioritize the health of our home planet. At its core is a focus on reducing carbon emissions and energy consumption." (Greenwood, 2021, p.5). This thesis will measure its sustainability with third-party tools and reduce its data transfers as much as feasible within the imposed technical and time constraints.

#### 1.3.1.5 *Engagement*

*Engagement* measures how actively a student responds to learning materials and in-class activities. In this thesis, we define someone as *engaged* if they agree or mostly agree with the majority of the statements in the *Student Course Engagement Questionnaire* (SCEQ). See section 3.3 *Measuring the engagement*.

With the problem statement and its definitions in place, it is time to explain why we need to create something new.

## 1.4 Shortcomings of Kahoot for this project

One might believe that Kahoot or a premium version of Kahoot will fulfill the product owner's wishes. An analysis of Kahoot were conducted to see if they could fulfill the product owner's desiderata. Unfortunately, four of the desiderata were not fulfilled:

1. **Paywall.** Comparing and compiling scores is behind a paywall.
2. **Insufficient leaderboard.** One must be able to visualize a leaderboard of all participants and anonymize participants below the top 5.
3. **No other in-class activities.** There is no support for other in-class activities. Similar concepts (aggregate, evolution) should be applied to non-Kahoot quizzes.
4. **Individual class leaderboards.** Showing individual class leaderboards can be tricky when several study programs take kahoots.

To further expand our knowledge, and to see if there were other alternatives, a competitor analysis were conducted (See section 3.1.1). However, no reasonable alternatives were found. Therefore, the project group had to develop a solution.

Having presented what the product owner is doing today, what desiderata he has, the current problem, and why Kahoot! does not fulfill the tasks at hand; we can now proceed to define the project's scope.

## 1.5 Project scope and limitations

It is necessary to determine the project's scope with available resources such as time, project participants, level of knowledge, and the project owner's restrictions. We have, therefore, created constraints. The list of constraints for this project are listed below:

1. **Only use MERN-stack.** The product owner has requested that we use only MERN-stack (MongoDB, Express, React, Node).
2. **Only focus on IDG2100.** Our study will be limited to students enrolled in NTNU's IDG2100 course. The IDG2100 course is similar to the IDG1292 course (where the problem originated) and is easily accessible for the project group.
3. **Kahoot only.** We will only develop and test for kahoots. Additional "in-class activities" are omitted due to a lack of time to develop new formats.
4. **Only measure our effect.** This thesis will examine the effect of the web application on student engagement; no other factors affecting student engagement will be considered.
5. **Not design gamification.** We will not investigate how gamification *should* be designed to promote engagement but rather the effects of the product owner's needs.

6. **Sustainability: only data transfers.** We will focus on transfer sizes rather than electricity consumption, as the latter is more challenging to quantify in terms of sustainability.
7. **No replacements.** We are not developing a replacement service for any currently available service but rather a complementary tool.
8. **WCAG is not a priority.** While the Web Content Accessibility Guidelines (WCAG) are critical for web development and were followed during the development phase, this thesis will not specifically address them in-depth.

## 1.6 Our approach to the solution

As mentioned in section *1.3 Problem statement* on page 14, the thesis consists of the three requirements below:

- a. Due to the lack of a suitable application on the market, we must develop one ourselves. When developing applications that others will use, keeping the user in mind during the design and development process is critical.
- b. To ensure the project's success, we must assess its impact on student engagement.
- c. Because we live in a world affected by climate change, we must be responsible web developers and do everything possible to mitigate our impact.

With the requirements above, the thesis is composed of three distinct problem areas; to reiterate, these are:

1. Design and develop the web application
2. Measure the engagement
3. Ensure sustainability

The three points are described in detail below.

### 1.6.1 Design and develop the web application

The first part of each chapter (Background and Theory, Methods, Results, and Discussion) will be about designing and developing the web application. The project group will employ competitor analysis, wireframing, scenarios, low-fidelity, usability testing, and high-fidelity prototyping to create a rich user experience. The web application will be created in React and is considered a *Single Page Application* (SPA) and will be a *Minimum Viable Product* (MVP). When different content needs to be displayed, a SPA loads only one web document and then updates the body content of that single document using JavaScript APIs like XMLHttpRequest and Fetch (Mozilla Developer, 2021).

## 1.6.2 Measure the engagement

To measure uniLeague's effect on student engagement, we used the 23-item *Student Course Engagement Questionnaire* (SCEQ) before and after participants used uniLeague in class. The SCEQ is a well-known questionnaire developed by Handelsman, Briggs, Sullivan, and Towler used to improve their required lower-division courses (See Handelsman et al., 2010).

We chose SCEQ instead of other similar questionnaires such as the *Motivated Strategies for Learning Questionnaire* (MSLQ) (see Pintrich and de Groot, 1990) and the *Student Engagement Instrument* (SEI) (see Fredricks and McColskey, 2012). These instruments were inappropriately targeted, focusing on the connection between engagement and motivation rather than the aspects we wanted to study. However, the SCEQ measures engagement among first- and second-year students participating in compulsory courses, which is ideal for our purpose. Other researchers have also validated the SCEQ to measure the impact of novel educational tools on student engagement (see Brown et al., 2017).

## 1.6.3 Ensure sustainability

To contribute to the UN's 13<sup>th</sup> sustainability goal, the group will ensure that the web application is sustainable. We must determine what can be quantified in the absence of *actual* carbon emissions. For this project, data transfers serve as the primary carbon emission indicator. As a result, the thesis focuses on measures that reduce the amount of data that Internet users must download (see section 3.4 *Sustainability*).

## 1.7 Structure of the report

Each chapter is divided into three parts, reflecting the macro-structure of the project itself. These chapters are *Background*, *Methods*, *Results*, *Discussion*, and lastly, *Conclusion*.

**The background chapter** summarizes our prior work and the theory that will guide the remainder of the thesis. The chapter explains gamification and engagement in an academic setting. Additionally, it presents theories related to design and development. Finally, it demonstrates how the web application we create directly impacts the climate and how we can mitigate our impact and contribute to the UN's sustainability goals.

**The methods chapter** details the procedures followed throughout the project. It includes the procedures for conducting our competitor analysis, the creation of wireframes, scenarios, low-fidelity prototypes, the high-fidelity prototype, and user testing. It explains the procedure for setting up the development environment and deployment of uniLeague. Then it covers the procedures behind the SCEQ and, lastly, goes over the measures taken to ensure sustainability.

**The results chapter** presents the methods' findings in order of importance. For example, we present screenshots from the design phase, usability test results, and sustainability metrics.

**The discussion chapter** discusses in detail the methods and their results. We compare our findings to those of other comparable studies. Lastly, the chapter explains how everything fits together.

**The conclusion chapter** concludes the thesis by concisely and explicitly answering its problem statement and problem areas.

We are turning now to chapter 2, *Background and theory*.

## 2 Background and theory

Finding pertinent background theory in projects like ours, where a technical web application is developed for a client, can be challenging. We create something that is frequently overlooked in research, as researchers frequently focus on broader contexts, larger systems, and broad perspectives rather than on specific individual cases.

As a result, we have chosen to employ best practices, techniques, and tools developed by practitioners in the relevant fields. This approach means that we will investigate and apply a broader background theory, even if it does not directly address the web application to be developed, as Aage Rognsaa recommends in his book *Bacheloroppgaven* (Rognsaa, 2015).

Before examining the theory, it is essential to preview what the current project extends.

### 2.1 Previous work

To accomplish the tasks at hand, we have concentrated on specific theories. The theories we chose to use are consistent with our previous work and are contextualized in this section. This section provides context behind the uniLeague project, including a recap of the previous project's most relevant conclusions. This background is vital because it influenced the uniLeague's design and development.

The product owner initially introduced his problem in the course "IDG3101 - In-depth Project" in the fall of 2021.

*In IDG1292 - Web Coding, we have used Kahoot! as a teaching tool for the last two years. Feedback given by students indicates that the Kahoot league motivates them. We want to study the feasibility of extending the league for a whole semester, academic course, or even a 3-year program. To do so, a digital tool to collect the results of the league and show statistics is required.*

The project group explored the problems presented by the product owner in the form of data visualization. The project group researched which graphs students found the most motivating under the project name "The Kahoot! League".

The following is a condensed presentation of the results from the previous project.

#### 2.1.1 Defining target audiences

Two user groups were identified, and associated user goals were central. The primary target audience is students at NTNU in Gjøvik. The secondary target audience is employees at NTNU in Gjøvik (Sandmæl, Hansen, and Schrier, 2021).



That is, first-year students in interaction design, web development, web design, and graphic design enrolled in IDG1292 – “Web coding,” and administrative users such as the course coordinator (product owner).

The primary goals of the students are to see their quiz performance and see the class leaderboard. The primary goals of the employees are to upload quiz results to the web application and see the class leaderboard (Sandmæl, Hansen, and Schrier, 2021).

Given the target audience, it was planned that these would be *student*, *teacher*, and *super admin* roles. Using these roles helps restrict specific tasks for each target audience in the web application.

### 2.1.2 Creating personas

The project group used personas to understand the target audience for the project better. Four *personas* were created (fictional characters created to represent actual users (Garrett, 2011, p. 49)). Three personas for the students and one for the employee. The personas reflect the results obtained by a quantitative study conducted by the same project group in IDG3101, mapping different motivational factors<sup>1</sup>. Table 1 contains a highly condensed version of the personas. See *Appendix 2: Personas from previous work* on page 139 for complete details.

Table 1. Excerpt from the Personas used during the "The Kahoot! League" project

Persona	Goal(s)
<b>Name: James Everett</b> <b>Occupation: Associate Professor at NTNU - ID faculty</b> <b>Age: 53</b> <b>Gender: Male</b>	James needs an application to upload his Kahoot! results. The application then compares the uploaded file to the database and adds where needed. James can then see the user's score and a whole result list. The user with the most points is preferred to be first.
<b>Name: Ahmet Bittner</b> <b>Occupation: Student</b> <b>Age: 28</b> <b>Gender: Male</b>	Ahmet wants an application that tracks progress and allows him to set, achieve, and de-select goals. He would like to know how many quizzes he got right. To see all students' results and progress, he should be able to toggle between them.
<b>Name: Alex Vestvik</b> <b>Occupation: Student</b> <b>Age: 21</b> <b>Gender: Male</b>	The best experience is to finish the Kahoot! quiz and compete with others. It is motivating.
<b>Name: Mathea Malmedal</b> <b>Occupation: Student</b> <b>Age: 19</b> <b>Gender: Female</b>	An application to establish her own goals and track her progress is perfect.

<sup>1</sup> This study is beyond the scope of this thesis, we will, therefore, not delve into it in detail.

### 2.1.3 Motivational graphs

Using qualitative interviews, a set of graphs that students felt were the most motivating was found. The group can conclude that students are motivated by graphs such as bar graphs and line charts (Sandmæl, Hansen, and Schrier, 2021). The charts should display task-oriented data points. It is more important to see personal improvement instead of displaying where a student is compared to the class average or other individuals.

### 2.1.4 Further development from IDG3101

After the "The Kahoot! League" project, the group made recommendations for future development (Sandmæl, Hansen, and Schrier, 2021). These recommendations include:

- **User testing.** Increase the number of design iterations and user testing.
- **Technical aspects.** The technical aspect should be thoroughly examined.
- **Privacy.** Personal information processing should be mapped.
- **Kahoot integration.** It should be investigated whether integration with the Kahoot platform is possible.

## 2.2 Changing the project name

During the current project, the project name changed from "The Kahoot! League" to "uniLeague." The name change was necessary because using the term "Kahoot" in the web application violates Kahoot's Terms of Service, section 3, "Licensed Rights.":

*The Kahoot! Brands<sup>2</sup> are the sole property of Kahoot!<sup>3</sup> or its licensors. The Agreement does not grant you any rights to use any Kahoot! Brand for any purpose, whether for commercial or non-commercial use. (Kahoot!, 2021)*

Multiple names were considered before settling on uniLeague. In Table 2 below, we present some of the names the group considered using.

Table 2. Names considered for the project

Name considered	Comment	Chosen?
QuizIt	Too similar to the already existing service "Quizizz."	X
StudentLeague	It appears to be excessively student-oriented and is lengthy	X

<sup>2</sup> "Kahoot! Brands" means all Kahoot! trademarks, service marks, trade names, logos, domain names, and any other features of the Kahoot! brand.

<sup>3</sup> "Kahoot!" means Kahoot ASA.

<b>ClassLeague</b>	Restricted to a single class and still a little lengthy	X
<b>uniLeague</b>	Appropriate for the entire university	✓

The preceding section demonstrates how "uniLeague" builds on our previous project, "The Kahoot! League." The solution will henceforth be referred to as uniLeague. The following section presents the theory underlying uniLeague.

## 2.3 Design and development

As mentioned in section *1.3 Problem statement* on page 14, the thesis is divided into three segments. This section will cover the theory for the first problem area, *Design and develop the web application*.

### 2.3.1 Competitor analysis

Understanding the landscape of solutions is essential to designing our web application. Competitor analysis provides a strategic insight into the characteristics, functions, flows, and emotions evoked by our competitors' solutions. Understanding these aspects of our competitors' products can strategically help design our solution to create a superior product and user experience (DaSilva, 2020; Levy, 2015, pp.66–68).

### 2.3.2 Mobile-first

More than two-thirds of the world's population (67.1%) now have access to a mobile phone, with 5.31 billion unique users expected this year, 2022. Since last year, the global total has increased by 1.8%, with 95 million new mobile users (Kemp, 2022). With such a large number of mobile users, it is clear that websites must be compatible with mobile phone devices.

As of July 1st, 2019, mobile-first indexing is the standard for Google Search (Google Developers, 2021). Mobile-first indexing means that a mobile-first design approach is desirable.

Due to the limited real estate available on a mobile screen, UX designers must prioritize their critical features. This mobile-first approach is built on the principle of progressive progression. When designers prototype or sketch a website layout, they begin with the appearance on a mobile device screen and progress to larger displays. Designers can now deliver the optimal user experience to the appropriate device (Morales, 2021).

### 2.3.3 Wireframing

Wireframes are a simplified representation of all the page components and their relationships in line drawings (Tomitsch et al., 2018, p 136; Garrett, 2011, p.128). Wireframes provide a formal framework for designers to think about and express what a design can do. The goal of

creating wireframes in this project was to outline a more user-friendly design. Because wireframes do not look or behave like a finished product, they are easy to develop and invite rapid modification. They accomplish this without using unnecessary high-fidelity information, such as images, fonts, colors, or typography, distracting from the main objective (Tomitsch et al., 2018).

### 2.3.4 Scenario

By imagining our users' processes, we can design and develop potential solutions to help meet their needs. A *scenario* is a short, straightforward narrative describing how a persona might try to fulfill one of the user's needs (see 2.1.2 *Creating personas* on page 21). Scenarios consist of a context-setting or situation state, personal motivations, and an imaginary procedure (Garrett, 2011, p. 68). See *Appendix 3: Scenario* on page 140.

### 2.3.5 Low-fidelity prototyping

Low-fidelity prototyping is a fast and straightforward method for translating design concepts into testable artifacts. A low-fidelity prototype is distinguished from the finished product by its interaction style, visual appearance, and level of detail. A low-fidelity prototype's primary and most important function is to verify and test the product's functionality, not its visual appearance (Babich, 2019). Due to the rapid nature of low-fidelity prototyping, designers have more time to iterate on designs in between usability tests (Walker, Takayama, and Landay, 2002).

### 2.3.6 Usability testing

Users require *usable* products (Garrett, 2011, p.48). *Usability testing* is essential because it helps us create a usable web application. Meaning uniLeague can be used by specific users to achieve a specific goal with efficiency, effectiveness, and satisfaction (Sandnes, 2018, p. 16). It is frustrating to deal with an inoperable web application. Usability testing helps us identify problems, improve processes, and learn the habits and preferences of target users. (Moran, 2019).

The group, as developers, is similar to the target audience. We are NTNU students who are enrolled in classes and actively participate in them. All three group members also work part-time as teaching assistants and have administrative experience.

As a result, it is tempting to believe our instincts regarding user interface design because we have many of the same qualities as a real user. Regardless, we vary from users in numerous ways, including their computer experience (and often passion) and understanding of the system's conceptual underpinning.

Consequently, we might design a screen that we believe is perfect, even though the same screen would not make sense to any real users in the target group who do not share our mental model of the system (Nielsen, 1993, p.13).

Nielsen (2012) argues that the group should not user-test a design iteration on more than five participants in *Why You Only Need to Test with 5 Users*. Adding more users will result in similar answers and meaningless learning outcomes. One wastes time by continuously observing the same results and gaining no new information. See Figure 4 below.

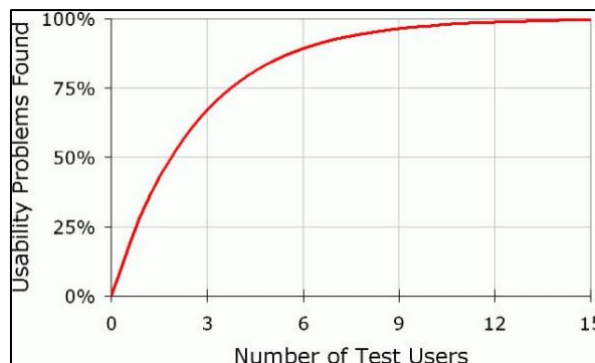


Figure 4. Chart displaying the connection between the number of test users and the percentage of usability problems found

#### 2.3.6.1 System Usability Score

The *System Usability Score* (SUS) questionnaire is a standardized usability questionnaire used to collect feedback regarding the usability of a prototype (Sandnes, 2018, p. 299). The questionnaire measures usability on a scale from 0 to 100. The survey consists of ten statements about the usability of the system. Including statements such as "I found the system unnecessarily complex" and "felt very confident using the system." (Jordan, 2010, pp.189–191). The complete questionnaire is appended as *Appendix 4: System usability score questionnaire* on page 151.

The participant responds to all statements on a Likert scale from 1 to 5 for the SUS score calculation. After every participant has answered the questionnaire, the total SUS score for that iteration can be calculated.

The following is a breakdown of the points for the responses:

- **Strongly Disagree:** 1 point
- **Disagree:** 2 points
- **Indifferent:** 3 points
- **Agree:** 4 points
- **Strongly Agree:** 5 points

The SUS score can be divided into five categories. These are *Awful*, *Poor*, *Okay*, *Good*, and *Excellent* (T, 2017).

Table 3. Distribution of SUS scores and their meaning

SUS Score	Grade	Adjective Rating
> 80.3	A	Excellent
68–80.3	B	Good
68	C	Okay
51–68	D	Poor
< 51	F	Awful

The average SUS score is 68. Getting a score of 68 means one is in the 50<sup>th</sup> percentile.

### 2.3.7 High-fidelity prototyping

High-fidelity prototypes make the development phase easier as all developers can use a single source of truth. High-fidelity prototypes resemble and function as closely as possible to the final product. All interface elements, spacing, and graphics look like the actual web application (Walker, Takayama, and Landay, 2002). Additionally, the high fidelity prototype includes similar-to-real content that will appear in the web application. Figma, a tool for creating high fidelity prototypes, can examine the design. Examining the high-fidelity design with Figma makes the developing phase easier because all developers have access to necessary information regarding elements' sizes, colors, and other visual properties (Babich, 2019; Figma, n.d.).

### 2.3.8 Using the MERN-stack

MERN is an acronym for *MongoDB*, *Express*, *React*, and *Node.js*. MERN is a JavaScript-based technology stack that makes the development process manageable. MERN is used to create full-stack (front-end and back-end) applications with JavaScript (Mehra et al., 2021).

#### 2.3.8.1 Front-end

Meta's (previously Facebook) ReactJS is an open-source JavaScript library for front-end development to create dynamic user interfaces. React uses a component-based architecture, where reusable components are created to increase the code reusability and reduce redundancy (Meta Platforms, Inc., 2022b).

#### 2.3.8.2 Back-end

*Node.js* is a scalable network application builder that uses an asynchronous event-driven JavaScript engine (Node.js, 2022). In other words, NodeJS is JavaScript that runs outside of a browser (Vasan Subramanian, 2017, p.7).

*Express* is a lightweight Node.js framework that makes it easier to write server code. In other words, Express is a Node.js web server framework that is like other server-side frameworks in terms of what it can accomplish (Vasan Subramanian, 2017, p.9).

*MongoDB* is a non-relational document-oriented database. It uses a JSON object for CRUD (Create, Read, Update, and Delete) operations (Vasan Subramanian, 2017, p.10).

### 2.3.8.3 Database

The data structure is complex since it requires balancing application requirements with database engine performance and application usage (i.e., queries, updates, and data processing) (MongoDB, Inc., 2021a).

A critical decision in data modeling is document structure and how the application represents data relationships. The data can be embedded (embedded documents store data relationships in a single document structure.) or manually reference data in other documents (a record in a database), collections (multiple documents), or databases (using another document's *\_id* field) (See section 3.2.2.1 *Defining a database structure*). The application can then run a second query to resolve the referenced fields (MongoDB Inc., 2021b).

Having covered the first problem area, we will now consider the second problem area, *measure the engagement*.

## 2.4 Engagement in the academic context

Following the methods of the first problem area, we have now moved to the methods of problem area two, *measure the engagement*.

We have sought out academic sources that study the effect of gamification in the education sector. There are many resources about the topic, and it consists of both old and newer research building upon a research-based basis. Our sources consist of books, studies, and academic journals. For example, *A Measure of College Student Course Engagement* by Handelsman, M.M., Briggs, W.L., Sullivan, N., Towler, A. Measuring engagement requires proper tools (Handelsman et al., 2010). We have been critical to resources originating from organizations, companies, and the like. The resources they write will be considered in line with advertising.

Academic resources have been selected to cover many theories that we can build upon, including positive and negative views.

The sources we use in this thesis have been found via Google Scholar using the search queries such as:

- “Gamification and engagement in education”
- “Class leaderboard effect on engagement”
- “Problem with gamification and engagement in education”
- “Gamification in education criticism”



The following pages will present the theory that we believe is most relevant to gamification and its effects on engagement in an academic setting.

In education, engagement is not a novel notion. Many educators have been interested in student engagement (Kim et al., 2018). Engagement with a course may increase academic performance (Handelsman et al., 2010). In recent years, the term “Gamification” has been a buzzword in the disciplines of education, owing to its purported ability to make in-class learning more motivating and engaging, using game components such as leaderboards, badges, and levels (Busch et al., 2014, pp.50–57; Bai et al., 2021).

However, the actual effect of gamification on learning elements such as engagement, motivation, and performance is hard to define and not fully understood (Sanchez, Langer, and Kaur, 2020). Multiple studies have praised its effect (e.g., Aleksic-Maslac, Rasic, and Vranesic, 2018; Vaibhav and Gupta, 2014; Rojas-López et al., 2019) and, in contrast, others have criticized gamification for its ineffectiveness (e.g., Mekler et al., 2017; Toda, Valle, and Isotani, 2018).

Furthermore, according to a study, visualizing a student's academic presentations (such as quiz results on a leaderboard) can help the student master the subject. Visualizations that compare a student's performance to a class average (such as a class leaderboard), on the other hand, make each student feel dejected and responsible for improving (Aguilar, 2017).

The studies mentioned above focus on multiple gamification and visualization aspects simultaneously, such as a combination of levels, badges, and leaderboards. Additionally, the visualization varies from displaying individual results, an absolute leaderboard, and relative leaderboards (refer to Bai et al., 2021). The target groups in the studies often vary from primary school pupils to post-graduate students. The effects are often measured based on grades in a course, interviews, or instruments other than ours.

It is, therefore, challenging to draw a clear conclusion of what a product like uniLeague does to an undergraduate's engagement in a mandatory course at NTNU. Consequently, we decided to study this area in more detail to find answers to how our web application affects the students' engagement in the IDG2100 course at NTNU in Gjøvik.

## 2.5 Importance of Sustainable Development Goals & Sustainable web design

We are now turning to the third problem area: *ensuring sustainability*. UN's Sustainable Development Goal (SDG) 13: “Climate Action” asks for immediate action to fight climate change. To meet SDG 13, we must make our web application sustainable. The following is a brief description of the UN's SDG 13.



Every country is legally bound to the international treaty on climate change called the Paris Agreement (2016) to fight climate change (United Nations, 2018). The treaty aims to limit global warming to preferably 1.5 degrees Celsius. Every country must reduce its carbon emissions (United Nations Framework Convention on Climate Change, n.d.).

In the context of reducing carbon emissions, the Information and Communication Technology (ICT) industry has gotten little attention as a significant contributor to carbon emissions. ICT is frequently lauded for creating efficiencies that assist lower the footprint of other industries (Belkhir and Elmeligi, 2018). For example, the average transatlantic business trip consumes 80,000 to 100,000 lb. of fossil fuel, which may be readily reduced by videoconferencing instead of traveling (Yi and Thomas, 2007).

However, It is crucial to note that the climate footprint is larger than one might assume. Its environmental impact is so significant that "If the internet were a country, it would be the sixth most polluting country [globally], with annual emissions similar to those of Germany." (Greenwood, 2021, p.5).

The number of Internet users is also expected to increase in the future. According to Cisco's predictions, by 2023, over 66% of the world's population will have access to the Internet, up from 51% in 2018, meaning the number of internet users will increase from 3.9 billion to 5.3 billion. As our reliance on the Internet rises, so does the demand for energy to power the technology that operates it (Cisco, 2020). According to a report by academics Anders Andrae and Tomas Edler, data centers are expected to consume 3–13% of global electricity in 2030, up from just 1% in 2010 (Andrae and Edler, 2015).

As data centers are becoming one of the world's fastest-growing sources of electricity consumption, and with so much of the world's electricity still provided by burning fossil fuels, they pose a real danger to fulfilling the Paris Agreement's goals (Greenwood, 2021, p. 75).

Due to the emissions generated by data centers and the rest of the ICT industry, all aspects of web development, including the uniLeague project, have a tangible impact on our planet. The more efficient uniLeague is, the less electricity it consumes and the fewer fossil fuels it needs to generate electricity for data centers. By lowering data transfers and thus being more energy-efficient, uniLeague will help reduce the needs of a data center and contribute to the UN's 13th SDG (Greenwood, 2021, p. 24).

By showcasing uniLeague's sustainable practices and low carbon footprint, uniLeague can also directly contribute to SDG target 13.3. "Improve education, awareness-raising and human and institutional capacity on climate change mitigation, adaptation, impact reduction, and early warning" (United Nations, 2018). By displaying our carbon emissions on our website, we increase awareness about the Internet's carbon footprint.

Because it is challenging to measure the actual carbon emissions, we need to find what we can measure. The primary factor that we can use as an indicator of carbon emissions is data transfers. Lower data transfers are preferred. For example, the more data is sent, the more energy consumed in the data center, telecom networks, and end-user devices. Therefore, this thesis will focus on data transfer sizes regarding sustainability.

This subject is best approached through a series of subheadings: *Green hosting*, *Content delivery network*, *Caching*, *Imagery*, *Typography*, *Bundle size*, *Code splitting*, and lastly, *Bringing information to the front*.

The following section provides a more detailed description of the headings.

#### 2.5.1.1 *Green hosting*

Web hosting is a critical component of the Internet and thus a critical component of the Internet's environmental impact. Web hosting's emissions exacerbate global warming and contribute to climate change. Although the nuances of green hosting are somewhat complicated, the fundamental concept of green energy is straightforward. A *green host* is a web host committed to using green energy (Greenwood, 2021, p. 84)<sup>4</sup>. Therefore, choosing a green host is one of the most obvious things that can be readily done for a sustainable website.

#### 2.5.1.2 *Content delivery network*

A *Content Delivery Network* (CDN) refers to a group of geographically distributed servers that quickly connect internet resources (Cloudflare, 2022). CDNs serve a crucial sustainability-related purpose. A significant portion of the energy consumed by the average website is used to transmit data from the host to the end-user. CDNs improve this by relocating data (like images and CSS files) closer to the end-user, thereby using less energy as the data has to travel a shorter distance (Wissmann and Garbers, 2021; Greenwood, 2021, p. 80).

#### 2.5.1.3 *Caching*

The number of times the browser sends requests to the server and the amount of data transferred is reduced by caching. *Caching* is a technique that stores a copy of a requested resource and returns it upon request (Mozilla, 2022). Caching is especially useful on pages where users visit a page several times, but the page's content does not frequently update, such

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<sup>4</sup> including owning renewables, power purchase agreements, buying renewable energy, buying renewable energy credits or carbon offsetting.

as uniLeague (Greenwood, 2021, p. 69). For example, when a user navigates from the "My Results" page to a specific course's page, the data is not re-downloaded but instead reused from the cache, reducing data transfers.

#### 2.5.1.4 Imagery

Images account for about half of total data transfer, making them the single most significant source of carbon emissions on a typical website (Greenwood, 2021, p. 22). Modern file formats such as WebP and AVIF should be used to reduce the impact of images. Additionally, compressing the images decreases the file size more.

#### 2.5.1.5 Typography

Converting external fonts to the most modern and efficient font file format supported by web browsers, WOFF2, is arguably the most straightforward measure to reduce font file size with no adverse consequences. The most efficient is to use system fonts pre-installed on end-user devices, such as Arial. System fonts require no server requests and data transfer (Mightybytes, 2022; Greenwood, 2021, p. 57).

Font files are very comprehensive. The fonts include characters in many languages, which are rarely utilized. *Subsetting* a font removes non-necessary characters from a font file to contain only the characters required for the web application (Stopper, 2019; Greenwood, 2021, p. 65).

#### 2.5.1.6 Bundle size

React defines *bundling* as the following:

*Most React apps will have their files “bundled” using tools like Webpack, Rollup, or Browserify. Bundling is the process of following imported files and merging them into a single file: a “bundle.” This bundle can then be included on a webpage to load an entire app at once. (Meta Platforms, Inc., 2022a)*

Bundling the entire application means that the user downloads the entire application, the *bundle*, at once. Keeping the bundle size as small as possible is crucial to make the process more efficient. If the bundle is large, the server must transfer a large amount of data to the user. The user must also wait for the download to finish before being able to use the application.

#### 2.5.1.7 Code splitting

As mentioned above, the user must download the entire bundle before using the application. The research group splits the bundle into smaller, more relevant parts by using code-splitting, significantly improving the performance and reducing the amount of data a user needs to download (Sustainable WWW, 2021).

We split the code for each route. Code-splitting the web application enables the user to download only the required elements, which can dramatically improve the app's performance.

While code-splitting does not decrease the total amount of code in the web application, it does avoid loading code that the user may never need and reduces the amount of code required during the initial load (Meta Platforms, Inc., 2022a). Code-splitting is sustainable because not every user needs all the code every time they visit uniLeague; as a result, we transfer fewer kilobytes overall.

#### *2.5.1.8 Bringing information to the front*

The user experience impacts the environment. We can minimize the impact by clever structural design. If a user regularly views three pages, but we design the site so they can get all the information they need on one page, we considerably reduce their carbon footprint by lowering page loads (Greenwood, 2021, p.37–38).

This section summarizes the theory underlying our web application, uniLeague. The chapter explained the origins of uniLeague and then explained how the research team can use multiple design methods to create a usable end-user experience. The chapter then presented theory regarding student engagement and gamification within education. The chapter ended by emphasizing the significance of sustainable web design and United Nations Sustainable Development Goal 13. The next chapter, *3 Methods*, describes the procedures and methods used to develop the application and conduct the study.

## 3 Methods

This chapter will describe how we designed, developed uniLeague, and measured uniLeague's effect on student engagement. As explained in the introduction, only conducting a study concerning engagement is insufficient. The following two sections (3.1 and 3.2) will help answer the first problem area, *Design and develop a web application* described in 1.3 *Problem statement*. They have been kept separate to make them easier to follow.

### 3.1 Designing the web application

#### 3.1.1 Conducting a competitor analysis

We seek direct knowledge of our competitors' positive and negative user experiences. The group conducted competitor analysis following the guidelines outlined in the book *Design. Think. Make. Break. Repeat. A Methods Handbook* (p. 42-43). Tomitsch (2018) lists the steps as follows:

1. Generate a list of potential internal and external competitors
2. Brainstorm variables
3. Identify the most relevant variables
4. Plot each of the four companies
5. Discuss the strength and weaknesses (see section 5.1.2.1 *Discuss the strength and weaknesses*)

As mentioned in chapter 1 *Introduction*, the project owner uses Kahoot! to conduct quizzes in class. To better understand the market, we evaluated both local and external companies used by NTNU today that offer a similar product or service that the product owner currently has access to. We have considered both design and functionality when conducting the competitor analysis.

##### 3.1.1.1 *Generate a list of potential competitors*

NTNU offers employees software, such as Blackboard Learn and Mentimeter. Blackboard Learn is a web-based virtual learning environment and learning management system that allows teachers to publish modules, quizzes, and other activities in a course. Mentimeter is a platform where a teacher can create engaging presentations with the options to do live polling and create quizzes.

As suggested by the instrument, the research group had at least one external competitor Quizizz, a popular alternative to Kahoot!. Quizizz is a gamified student engagement platform where a teacher can conduct formative assessments and create quizzes. We will, therefore, evaluate the services of Blackboard Learn, Mentimeter, and Quizizz to the currently used service, Kahoot.

### 3.1.1.2 *Brainstorm variables and write them down*

The following criteria were put in a table to evaluate each competitor; *Capabilities for instructors and students*, *Capabilities that are the same*, *Poor capabilities*, and *Product owner wishes*. The table can be found in *Appendix 6: Complete competitor analysis* on page 155.

To evaluate Blackboard Learn, Mentimeter, Kahoot! and Quizizz, the group visited each platform's homepage to identify their respective features. In addition to browsing the homepage, an e-mail to their customer support was sent to validate the information or check if the platform had some features hidden from its home page. See *Appendix 5: E-mails sent to customer support* on page 152.

We sought direct knowledge of our competitors' positive and negative user experiences, as advised by Levy, 2015. To get more insight into what other users thought of the platforms, we browsed TrustRadius<sup>5</sup>, where users give product feedback and reviews.

### 3.1.1.3 *Review and refine the list to identify the variables most relevant.*

Ten wishes were assessed as most appropriate after the meeting with the product owner mentioned in *1.2 Desiderata*. These were:

1. Track students' progress through a semester
2. Graphical representation of quiz results
3. Display the students in the top five
4. Keep everyone outside the top five anonymous
5. Reduce human error
6. Give points for other in-class activities
7. Scale the number of users
8. Further develop functionality
9. Manage users
10. Let students share their results

### 3.1.1.4 *Plot each of the four competitors*

The following table lists all competitors to establish a baseline. The capability column has been filled out using the ten wishes from section *1.2 Desiderata*. A revised analysis where uniLeague has been added can be found in section *4.2.1 Competitor analysis results*.

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<sup>5</sup> See <https://www.trustradius.com/>

Table 4. Competitor analysis

Capability	Kahoot! EDU	Blackboard Learn	Mentimeter	Quizizz
(1) Track student and class progression	✓	✓	✗	✓
(2) present a graphical representation of quiz results to the students	✓	✓	✗	✗
(3) top five students on a leaderboard	✓	✗	✗	✗
(4) Anonymize names outside the top five students on the leaderboard	✓	✗	✓	✓
(5) Combine reports to reduce human error	✓	✓	✗	✗
(6) Give points for other in-class activities besides the quiz	✗	✓	✗	✗
(7) Scale the number of users	✓	✓	✓	✓
(8) Further develop functionality	✗	✗	✗	✗
(9) User management	✓	✓	✗	✓
(10) Sharing results	✓	✗	✓	✓
Price billed annually (as of spring 2022)	\$25/ per educator monthly	N/A	\$10 / \$25 monthly	\$19 per host monthly

### 3.1.2 Creating wireframes

Combining wireframing with the "Crazy-8" sketching technique allows the research group to produce many design alternatives. Pen and paper were utilized to conduct the "Crazy-8" technique. We constricted ourselves to only design for mobile screens. See 2.3.2 *Mobile-first*. Using dot voting, three wireframes from each iteration were picked and created in *Balsamiq*, a digital tool for creating low-fidelity prototypes using "drag and drop" components.

The group used the Crazy-8 template by Levey (2017) to get started quickly. The template includes eight rectangles where we can sketch wireframes. The group could choose freely from six topics: *About*, *Upload*, *Admin*, *Leaderboard*, *My results*, and *Settings*. The goal was to create eight different wireframes, each within one minute. There were two rounds of Crazy-8.

The wireframes were presented to the other group members. Then they were scanned and put into *Miro*, an online collaborative whiteboard. Each member got four dots each, using the dot voting technique to vote for the wireframes they felt would become most usable for the user. Four wireframes got selected to get further designed in round two.

A new round of Crazy 8 was conducted with the abovementioned candidates. Each member got two minutes for each of the four wireframes to design further. After the wireframes were presented to each other, they were scanned and added to *Miro*. Each group member got four dots to use with dot voting. The selected wireframes can be seen in 4.2.2 *Wireframing results* and recreated to a low-fidelity prototype in 4.2.4 *Low-fidelity prototype results*. The winners were recreated in *Balsamiq*.

### 3.1.3 Creating scenarios

The group used scenarios for usability testing. Scenarios are narratives describing an action a user wishes to perform. The personas described in section 2.1.2 *Creating personas* have established a context containing characters with goals and a sequence of events that concludes with a result (Baxter, Courage, and Caine, 2015, p.46).

The group used the roles defined in section 2.1.1 *Defining target audiences*, to create scenarios. All scenarios were constructed using a five-column table provided as a template in *Design. Think. Make. Break. Repeat. A Handbook of Methods*. See Appendix 7: *Template for Scenario* on page 156156.

### 3.1.4 Creating low-fidelity prototypes

We chose digital low-fidelity prototyping over paper prototyping because Sefelin, Tscheligi, and Giller's study (2003) indicate that participants gain "more freedom to explore a system without causing 'unnecessary' work for the [moderator] and that they feel 'less observed.'"

The low-fidelity prototype uses the mobile-first technique mentioned in section 2.3.2 *Mobile-first* and includes three distinct views for each role mentioned in section 2.1.1 *Defining target audiences*. Each view is created in two iterations. The first iteration is derived from the scenarios described in 3.1.3 *Creating scenarios* and the wireframes in 3.1.2 *Creating wireframes*. The second iteration is designed after the initial usability tests, looked into further in the next section. Improvements from the usability tests are used to design the high-fidelity prototype mentioned in section 2.3.7 *High-fidelity prototyping*.

One example of design improvements made between iterations is seen in Figure 5. The course buttons in "My results" have been made more prominent, while "Individual course results" have a snippet of the leaderboard for that course, and the different quiz buttons are more prominent. The most significant difference between the two iterations is that the navbar has been completely changed.



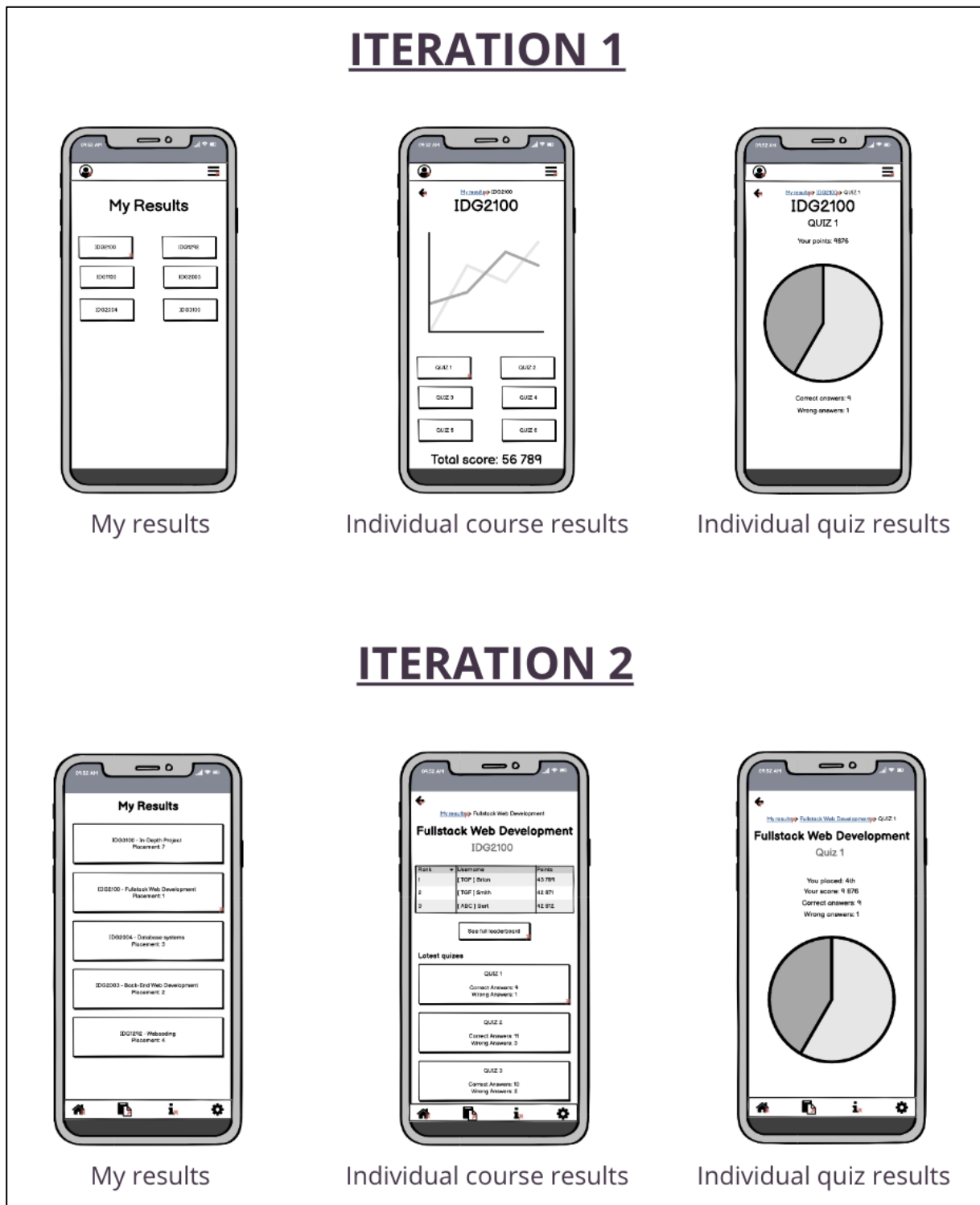


Figure 5. The first and second iteration of the low fidelity design

### 3.1.5 Conducting a usability test of the low fidelity prototype

To ensure that the designer's mental model of the product matched the user's mental model and that the design was usable, we conducted usability tests with the low-fidelity prototype.

Before we continue, it is critical to understand that usability is not a one-dimensional quality of a user interface. Our usability test will measure the aspects of *efficiency*, *effectiveness*, and *satisfaction* (Jordan, 2010, pp.189–191).

#### 3.1.5.1 Measuring efficiency

The efficiency is measured by the time a participant finishes a given task in seconds and milliseconds. However, we found this challenging and will further explain it in section 5.1.1.1 *Usability Test*.

#### 3.1.5.2 Measuring effectiveness

The effectiveness is measured in the number of errors the participant makes during a scenario.

#### 3.1.5.3 Measuring satisfaction

The participant's satisfaction is measured by comments during the test and the overall system usability score. The system usability scores will be further explained and examined in section 4.2.5.2 *System usability score*.

#### 3.1.5.4 The instrument for usability testing

When conducting the usability tests, we used the template given in *Design. Think. Make. Break. Repeat. A handbook of Methods* (See Appendix 8: *Instrument for usability testing* on page 157). The template allows the group to compare how participants complete a task (Sandnes, 2018, p.294).

We replicated the template to a Microsoft Word document to make it easier to duplicate and save for later. The template consists of five columns: *Task(s)*, *Success*, *Time to complete*, *Number of Errors*, and *Notes/Observations*. Each column has five rows. Each participant is only referred to as a number.

In the Task(s) column, we write the explanation of the scenario and the task a participant will have to undergo.

*Example: You have participated in a Kahoot! -quiz in the IDG2100 lectures. The lecturer has uploaded the results, and you want to know how many correct and incorrect answers you got in quiz one in IDG2100. Your task is to find how many correct and incorrect answers you got.*

The success column is an enumerated type. Its values can be 0 = not completed, 1 = completed with difficulty or help, 2 = easily completed.

The time to complete the column tracks the duration it takes to complete a task. The duration is measured in seconds and milliseconds.

The number of errors is counted as a single number. We have defined an error as an action not needed to complete the given task. For example, navigation to a page where the user will not be able to complete their task is considered an error.

The notes/observations column tracks a user's actions to solve a task and quotes when the participants think aloud.

*Example: The user wants to select a course and upload a file. The user then clicks on the leaderboards tab but finds nothing there. Then taps the tools icon. Presses "upload quiz." Then selects the semester and uploads quizzes to the system.*

#### 3.1.5.5 Preparing the usability test

After replicating the template, the group conducted a pilot test. Pilot tests assist the group in developing a shared understanding of the circumstances. Furthermore, flaws and practical difficulties with the usability test may be identified and corrected (Sandnes, 2018, p.294).

#### 3.1.5.6 Finding participants

It was important to find five suitable participants for the usability testing (Nielsen, 2012; Tomitsch et al., 2018, pp.126–127; Rubin and Chisnell, 2008, p.72). As suggested by Nielsen, the group should recruit members from both target groups—students and employees in our case.

To recruit student participants, the group sent out a mass e-mail to all registered students who actively took the IDG2100 course during the spring semester of 2022. In total, 24 e-mails were sent.

The group created the mass e-mail in Microsoft Word by following the *use mail merge to send bulk e-mail messages* by Office Support (Microsoft, n.d.). The e-mail included an introduction to the project, an explanation of why the recipient was invited, and a list of time slots where the recipient could meet the group to conduct a usability test (see *Appendix 9: E-mail sent to students for usability testing* on page 158).

Seven students responded to our invitation via e-mail. The group asked another three students in the communal area for bachelor students at Mustad Næringspark. The first five participants tested our first iteration of the low-fidelity design. Then, later that week, the last five students tested the second iteration of our design.

To recruit administrator participants, the group sent out a mass e-mail to all employees at the department of design at NTNU in Gjøvik. The e-mail included an introduction to the project, explaining why we invited the recipient (see *Appendix 10: E-mail sent to administrators for usability tests* on page 160). A total of five administrators responded and booked a timeslot.

After iterating the design, only one administrator had the time to test the new design. The same administrator had also tested the first iteration. To find two more participants to test the administrative tasks, the group reached out to two teaching assistants in the communal area.

#### 3.1.5.7 *Conducting the usability tests*

Two group members were present during the usability test and one participant from the target group. The group decided to have two roles during these tests. The first role is the moderator. Besides the test subject, the moderator is the only one who speaks. The moderator sits next to the test person in front of the prototype to establish an equal relationship. The Moderator explains the task to the test subject and interferes when necessary (Sandnes, 2018, pp. 297).

The second role is the timekeeper. The timekeeper utilizes a smartphone stopwatch app to time the test subject. When the test subject completes a task (indicated by the participant getting to the correct screen or completing the task at hand. e.g., Saying the user's name at the top of the leaderboard), the timekeeper shows the time to the moderator. The time is recorded in the Usability test template.

Because usability testing is intended to improve the design rather than find defects, the above procedure was repeated for the second design iteration (Nielsen, 2012). To compare results, the group used identical templates and tasks. The results can be seen in section 4.2.5 *Results from usability testing*.

#### 3.1.5.8 *System usability scale questionnaire*

After each usability test, the group asked the participant to fill out a System Usability Scale (SUS) questionnaire. These questions prompt unfiltered responses from participants and need minimal interaction. To obtain reliable and truly unfiltered feedback, the group kindly reminded the participant of the questionnaire's anonymity and to be as honest as possible.

#### 3.1.5.9 *Calculating the SUS score*

Each response to the usability questionnaire is insignificant on its own. To make the questionnaire valuable, we must summarize all responses from a single iteration.

To determine the total score for all odd-numbered questions ( $X$ ), add them and subtract five (see Equation 1. Sum of odd-numbered questions ( $X$ )).

*Equation 1. Sum of odd-numbered questions ( $X$ ).*

$$X = (\text{sum of question \#1, \#3, \#5, \#7, \#9}) - 5$$

Then, subtract 25 from the total score for all even-numbered questions to arrive at  $Y$  (See Equation 2).

*Equation 2. Sum of even-numbered questions ( $Y$ ).*

$$Y = 25 - (\text{sum of question \#2, \#4, \#6, \#8, \#10})$$

Lastly, add  $X$  and  $Y$ , and then multiply this sum by 2.5 (Equation 3)

*Equation 3. Calculation of SUS score.*

$$SUS\ score = (X + Y) * 2.5$$

Repeat the formulas above for all responses and calculate the average for the prototype used during the usability test.

### 3.1.6 Creating the high-fidelity prototype

The low-fidelity prototype mentioned in section 3.1.4 *Creating low-fidelity prototypes* is used to create a high-fidelity prototype, with improvements made based on feedback from usability testing.

The high-fidelity prototype is created for desktop and mobile devices. Three distinct views are created for each of the roles mentioned in section 2.1.1 *Defining target audiences*. Each view contains the functionality required for each role. While the functionality varies, they all adhere to the same design concept. Reusable components are utilized to group components with similar functionality across multiple views or pages to adhere to the same design. Typography and color variations are also organized using Figma's "styles" feature, a design tool used to create high-fidelity prototypes.

An example of a reusable component created is the "course cards" and "quiz cards," as seen in Figure 6. Each has three different states that change throughout the design; *default*, *hover* and *clicked*.

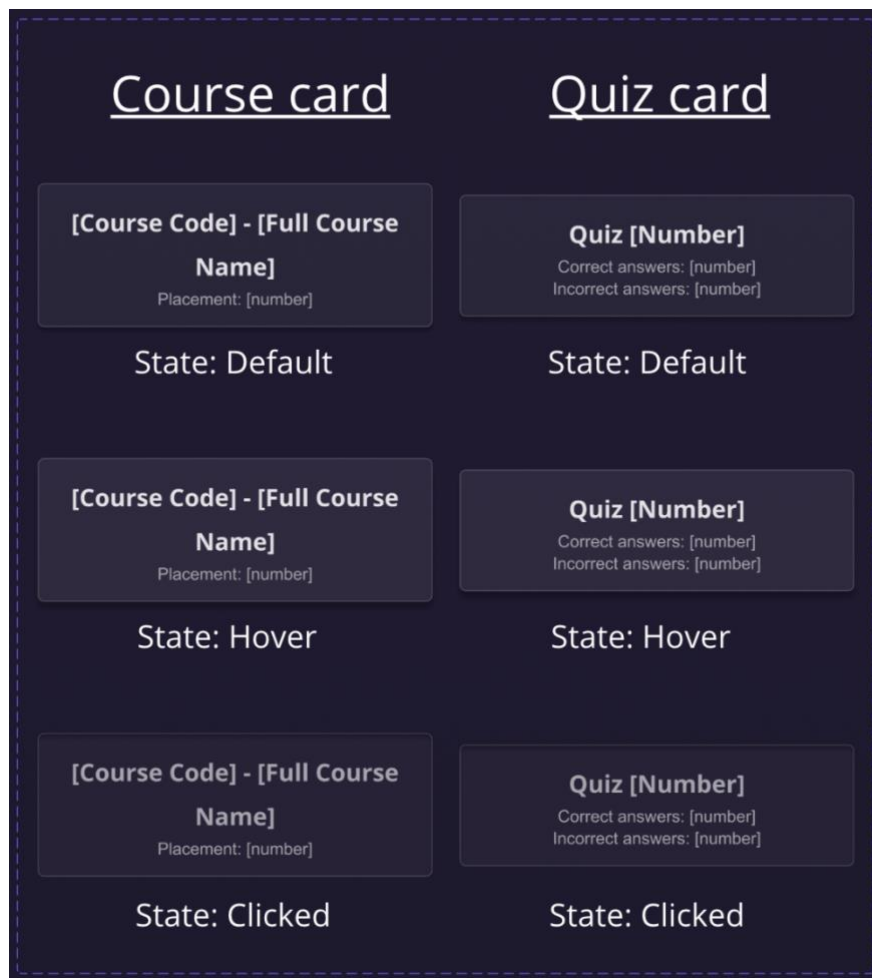


Figure 6. Reusable design components used in the high-fidelity design

This section has explained how the group used different design methods to design uniLeague. The section described how the competitor analysis created a foundation for the design. It demonstrated how design went from wireframes to a low fidelity, and lastly to a high fidelity design. We will explore the results of the design methods and showcase screenshots in section 4.2 *Results from design methods*. Now let us turn to the development of the web application.

## 3.2 Developing the web application

This section will look at the methods used for developing the web application, which is the second part of the first problem area *design and develop a web application*. The methods mentioned here are not in chronological order but of importance.

### 3.2.1 Setting up the front-end

As mentioned in section 1.6.1 *Design and develop the web application*; the application has been created in React, as what we can call a Single Page Application. The “create-react-app” toolchain was utilized to start the project's front-end. This toolchain creates the front-end build pipeline, i.e., all necessary files. The file structure is divided into the “public”-folder and the “src”-folder. The “public”-folder contains the compiled files the browser reads, while the “src”-folder contains the user-generated files (See Figure 7). The “src”-folder was divided into six: *api*, *assets*, *components*, *css*, *helpers*, and *routes*.

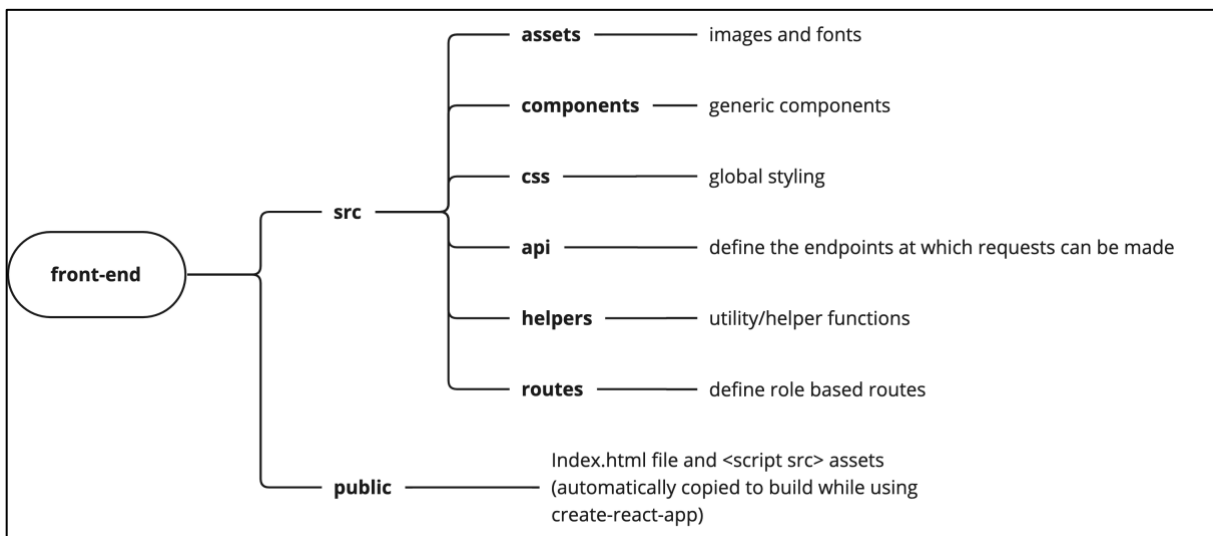


Figure 7. File structure for the front-end.

The “api”-folder contains the files used to send requests to the back-end. It has two files, “apiCalls.js” and “axios.js.” The first folder contains the requests, and the second contains the configuration for *Axios*, a promise-based HTTP client for the browser and Node.js. “Assets” contains images and font files. “Components” contains all the components that are used in the project. The “css” folder contains the global stylesheets. “Helpers” has code snippets that are common and used in several places, such as functions. Finally, “routes” holds the authentication of different routes in the application, i.e., a student can not access a route made for teachers and admins.

After establishing the file structure, development could begin. The first step was to create the project's global styles. These were CSS files that restored some of the browser's default styles. Following that, we imported our color palette and typography.

Next, the navigation bar and footer were developed. The application's various routes were added, and some placeholder text. The login component and the role-based view were then added. Creating role-based views required connecting the front-end and back-end. After developing the primary components, such as the leaderboard, and cards, we added

functionality to each component. At this stage, dummy data was used instead of actual back-end data.

After completing the back-end with actual data, the API calls were created, and everything was connected. After that, extensive testing was conducted to ensure that everything worked as expected. After establishing a functional prototype, the web application was deployed to a server see 3.2.4 *Deploying the web application*.

## 3.2.2 Setting up the back-end

### 3.2.2.1 *Defining a database structure*

As described in 2.3.8.3 *Database*, structuring a database is particularly challenging because one must consider the application's performance requirements while also being able to balance the application's use (i.e., queries, updates, and data processing). Five of MongoDB's recommended rules have been implemented to help structure the database (Karlsson, 2020). Lastly, *MongoDB Atlas*, a multi-cloud application data platform, is used to host the database, simplifying deploying and managing the database.

The following rules advocated by MongoDB are:

1. **Favor embedding.** Favor embedding unless there is a compelling reason not to
2. **Limit embedding.** Needing to access an object on its own is a compelling reason not to embed it
3. **No JOIN or \$lookups.** Avoid JOINS and \$lookups if they can be, but do not be afraid if they can provide a better schema design
4. **Limit arrays.** Arrays should not grow without bound
5. **Assess requirements.** How one models the data depends – entirely – on the particular application's data access patterns.

The database structure is divided into five *schemas*. The schemas are created using *Mongoose*, an Object Data Model (ODM), where each schema corresponds to a MongoDB collection. Each collection defines the structure of the documents contained within that collection. The following list contains the schemas:

1. user
2. refreshToken
3. studyProgramme
4. course
5. kahoot

*Appendix 11: Database's various schema, fields and schemaTypes* on page 161 provides an overview of the database's various document types, fields, and data types. To summarize, the user schema contains user-specific information. The refreshToken schema contains information about *the refresh token* and is used for authentication; IP addresses are recorded



against the token to help identify any anomalous or malicious activities. The studyProgramme schema contains information about a studyprogramme derived from JSON data extracted from the web development study program website<sup>6</sup>; see *Appendix 12: JSON data extracted from the web development study program* on page 164 for a snippet of the extracted JSON data. The course schema contains course-related information, and the kahoot schema contains data regarding kahoots. See Figure 8 for a visualization of the database structure.

The following database structure decisions were made using the five rules proposed by MongoDB and are best detailed below.

### **Favor embedding**

studyPeriod is embedded inside the studyProgramme schema. When accessing a studyProgramme, the studyPeriod information is also needed—the same implies to kahoots, where finalScores are embedded inside the kahoot schema.

### **Limit embedding**

The need to access "activities" data without utilizing studyProgramme data necessitated the extraction of courses from the studyProgramme schema. The same implies to the refreshTokens schema without utilizing users schema data.

### **No JOIN or \$lookups**

With the current database structure, there are only two places where it is needed to do a \$lookup, one for courses and one for kahoots.

### **Limit arrays**

The only place where an array grows without bound is "activities" sources, but there is a limit to how many activities a teacher can upload based on the timeframe a semester has.

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<sup>6</sup> [https://www.ntnu.no/web/webutvikling-bwu-/studiets-oppbygging?p\\_p\\_id=studyprogrammeplannerportlet\\_WAR\\_studyprogrammeplannerportlet\\_INSTANCE\\_uMhlebzfuY6g&p\\_p\\_lifecycle=2&p\\_p\\_state=normal&p\\_p\\_mode=view&p\\_p\\_resource\\_id=studyplan&p\\_p\\_cacheability=cacheLevelPage&code=BWU&year=2019](https://www.ntnu.no/web/webutvikling-bwu-/studiets-oppbygging?p_p_id=studyprogrammeplannerportlet_WAR_studyprogrammeplannerportlet_INSTANCE_uMhlebzfuY6g&p_p_lifecycle=2&p_p_state=normal&p_p_mode=view&p_p_resource_id=studyplan&p_p_cacheability=cacheLevelPage&code=BWU&year=2019)

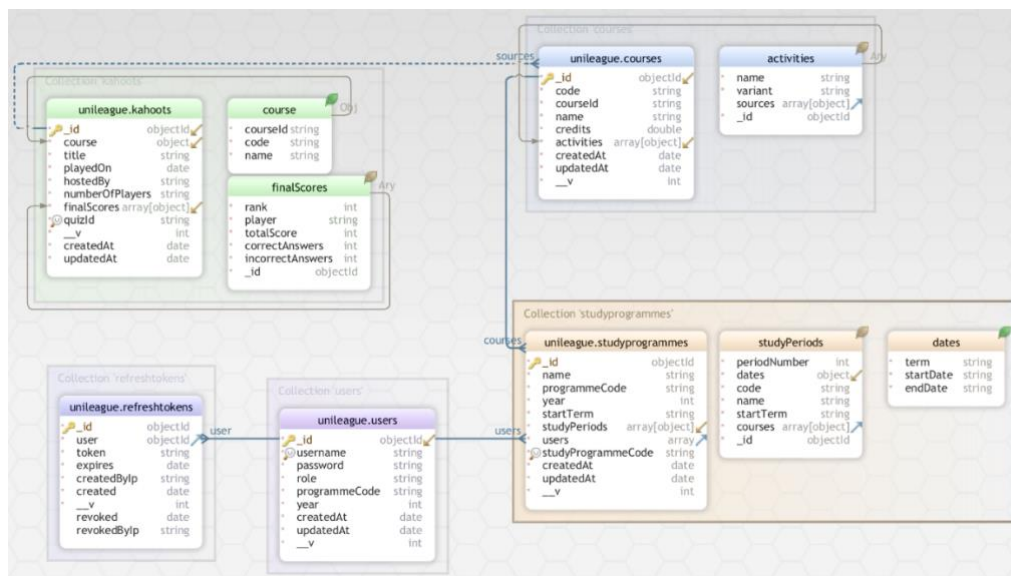


Figure 8. Visualization of the database structure, created using the tool DbSchema

### 3.2.2.2 Defining a file structure

As described in section 3.2.2 *Setting up the back-end*, the back-end has been created using Node.js, Express, and MongoDB. The file structure (see Figure 9) is divided into seven folders:

1. config
2. controllers
3. middleware
4. models
5. routes
6. tmp
7. utils

The "config"-folder contains configuration files "mongoose.js", "excelToJson.js" and "passportAuth.js". We use the first configuration file to connect to MongoDB, and the second is used to extract Excel data from quiz results. The third is to create an authentication strategy using *Passport* that authenticates users using a *JSON Web Token* (JWT) and validates them. It authorizes an *endpoint*; a URL focused on creating a request. The "controllers"-folder contains the logic for handling route requests and has five files corresponding to each route endpoint.

The "middleware"-folder contains four middleware files: "async.middleware.js," "authorize.middleware.js," "role.middleware.js," and "validate.middleware.js." The first is used as a *wrapper*, which intends to call one or more other functions, making routes *asynchronous*, running in parallel with different functions. The second is used to authorize a

single route endpoint, and the third is used only to enable users with a specific role to access an endpoint. Lastly, the fourth validates a request against a *Joi schema object*, a library for validating JavaScript objects.

The "models"-folder contains five schemas that define the structure and content of the data, further described in section 3.2.2.1 *Defining a database structure*. The "routes"-folder contains routes. The "tmp"-folder is a temporary folder that contains the quiz results uploaded to the application. The last folder, "utils," includes three utility/helper-functions files: "calculateSemester.js," "errors.js," and "generateTokens.js." The first utility/helper function calculates the current semester using the year given by the study program. The second is used to create error codes used for throwing errors depending on the request made. The third is used to generate a JWT after a user has been authorized.

Figure 9 shows a diagram of the file structure in the back-end.

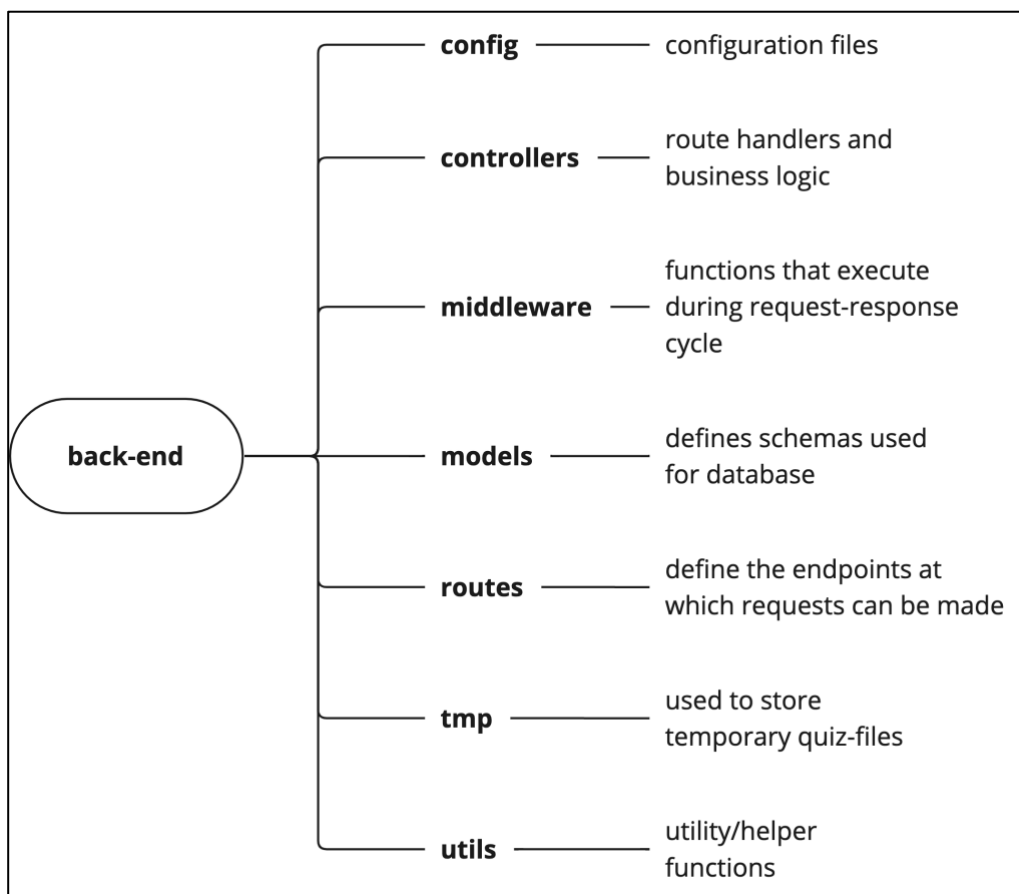


Figure 9. The file structure in the back-end.

### 3.2.3 Populate the web application

The web application has been populated using kahoots instead of other alternatives (e.g., Mentimeter, Blackboard Learn, or Quizizz results). Data from real kahoots has been used, similarly to what the product owner currently does. Using data from real kahoots may require the storage of personal data. We have taken steps to anonymize this data.

#### 3.2.3.1 Using Kahoot! Quizzes

The kahoots have six to eight multiple-choice questions. The number of correct answers and response time determine one's score. The questions were based on the lecture's content. The group created the questions and sent them to the product owner/lecturer. After the lecture, the lecturer would play Kahoot and upload the results.

#### 3.2.3.2 Ensuring Privacy

It was essential to keep the anonymity and respect the privacy of all participants during the research. Multiple approaches were considered before moving on. Table 5 lists the approaches considered below.

Table 5. Approached considered when playing kahoots with the study group

Approach	Collects personal data	What data?
Use FEIDE-username and user-generated passwords <sup>7</sup>	Yes	FEIDE-username
Invite students to the platform via their e-mail	Yes	E-mail
Generate random usernames and passwords	No	None

If we wanted to use FEIDE-username, we had to contact NSD and file a request for storing personal data. This request could take up to 30 days. Since time was not on our hands, we decided to use an approach that would not store personal data. The solution was to generate random usernames and passwords.

To generate 26 passwords, the group used a password generator<sup>8</sup>. Settings for this tool were:

- Password Length: 6
- Include Symbols, Exclude Ambiguous Characters: false,

<sup>7</sup> The product owner wanted to use the FEIDE usernames, but the project team did not meet the FEIDE integration requirements. This thesis will not elaborate on it.

<sup>8</sup> See <https://passwordsgenerator.net/> for password generator tool.

- Include numbers, include lowercase characters, include uppercase characters, exclude similar characters, Generate on your device: true

The group used the Wikipedia article *Characters of the Marvel Cinematic Universe* to pick recognizable and rememberable usernames. Usernames were picked from the *Central Characters*<sup>9</sup> section. Names were then converted to lowercase, and spaces were removed.

### 3.2.3.3 *Distributing login credentials*

The username and password were distributed by printing the names and passwords on paper and cutting out the pair in strips. The strips were then placed face down on a table for the students to choose. This method was chosen to protect the students' anonymity. If a student forgot their password, they were advised to contact the lecturer and provide their username.

## 3.2.4 Deploying the web application

This section will look at how the web application was deployed and ready for testing. To set up a *Droplet*, which is a cloud server on DigitalOcean, the following five guides have been used:

1. **Droplet.** How to create a Droplet from the DigitalOcean control panel (Refer to DigitalOcean, 2018)
2. **Nginx.** How to install Nginx on Ubuntu 22.04 (Refer to Garnett, 2022)
3. **SSL.** How to Secure your website using certbot, Cloudflare, and Nginx (Refer to Duan, 2022)
4. **Serve.** Deploy full-stack Nodejs MongoDB Express backend and React frontend on Digital Ocean with NGINX single Droplet. (Refer to Li, 2021)

The first guide is the initial server configuration that creates the *root user*, an administrative user with elevated privileges in a Linux system. Setting up NGINX, the webserver, and configuring the server blocks are covered in the second guide. The third guide ensures data encryption between the server and the end-user. The fourth and final guide describes deploying the front-end and back-end on a single droplet using *PM2*, a process manager for Node.js applications.

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<sup>9</sup> See

[https://en.wikipedia.org/w/index.php?title=Characters\\_of\\_the\\_Marvel\\_Cinematic\\_Universe&oldid=1087141123](https://en.wikipedia.org/w/index.php?title=Characters_of_the_Marvel_Cinematic_Universe&oldid=1087141123) for complete list of Marvel characters.

## 3.3 Measuring the engagement

Let us now turn to the instrument used to measure the effect of uniLeague on student engagement. This section will show the methods used to answer the second problem area, *measure the engagement*. The instrument used was the *Student Course Engagement Questionnaire* by Handelsman et al.

### 3.3.1 Questionnaire purpose

The 23-item *Student Course Engagement Questionnaire* (SCEQ) by Handelsman et al., was utilized to quantify web development student engagement before and after using uniLeague in IDG2100, a mandatory full-stack development course at NTNU in Gjøvik. Measuring both before and after the uniLeague implementation means our study uses a pre-questionnaire and a post-questionnaire.

The instrument has gained recognition from researchers Stephen Brown, Alex Bowmar, Sue White, and Nicola Power. They state in their evaluation of the instrument:

*We suggest the SCEQ is an appropriate instrument to quantify course engagement in [undergraduate nursing and paramedicine students] and this type of course. A valid tool to measure course engagement in these students is pertinent, as it could be used to identify the impact of novel pedagogies on student engagement (Brown et al., 2017).*

### 3.3.2 Method chosen

The group distributed the instrument in the form of a computer questionnaire. The group utilized Microsoft Forms to host the questionnaire. This approach allows the collection of data from multiple test subjects simultaneously.

The group presented the pre-questionnaire link via Keynote after finishing a kahoot at the end of a lecture in week 9. A week later, the group posted the pre-questionnaire on the IDG2100 Blackboard page, notifying all students.

The group presented the post-questionnaire link and QR code at the end of the lecture. Because the post-questionnaire got a lukewarm response, we invited every enrolled student personally via e-mail as this would give more responses than a general invitation (de Leeuw, How, and Dillman, 2012, p.270). The e-mail was sent after the Easter break in week 16, two weeks after the post-questionnaire opened.

### 3.3.3 Why this method

Using a computerized questionnaire is more manageable than other options, such as conducting in-depth interviews. Multiple factors led to the selection of a computerized questionnaire as our method. The critical factors can be listed as follows:

1. High comparability

2. Low cost
3. Anonymity
4. Minimizes interviewer bias

#### *3.3.3.1 High comparability*

The SCEQ employs a Likert scale to assess engagement. It is straightforward to categorize and present the results by assigning codes to responses (for example, "less like me" = 1 point, "more like me" = 5 points). A higher score indicates a greater degree of agreement with each statement. Both pre-and post-questionnaire results use the same scale, making comparisons easier (Colosi, 2006).

#### *3.3.3.2 Low cost*

Computer questionnaires are a low-cost method of gathering more extensive information that does not require any facilitators or laboratory equipment. Additionally, by utilizing a computer questionnaire, the group saves time on interview scheduling because the respondent may complete the questionnaire at any time of day or night (de Leeuw, How, and Dillman, 2012, p.288).

#### *3.3.3.3 Anonymity*

The computer questionnaire also makes it easy to keep a superior level of anonymity. By not collecting unneeded data such as the participant's name, personal identification number, date of birth, address, IP address, e-mail address, sound recordings, or other background data, one avoids working with the 'NSD - Norsk senter for forskningsdata' approval. Such approval from NSD requires a 30-day notice and would interfere with the project's deadlines (Schwencke and Andersen, 2020, pp. 151–152).

#### *3.3.3.4 Minimizes interviewer bias*

Using a computer questionnaire removes the interviewer from the process, minimizing interviewer bias and giving us more accurate reporting (de Leeuw, How, and Dillman, 2012, p.288). Because multiple group members also are teaching assistants who see the students perform in class, it was essential to minimize interviewer bias when mapping student engagement.

### **3.3.4 Selection of representatives**

Twenty-six students were eligible to participate in the questionnaire. The questionnaire was only open to students enrolled in the IDG2100 – Full-stack web development course at NTNU in Gjøvik during the spring of 2022.

### 3.3.5 Questionnaire design

The 23-items reflect what undergraduates and faculty describe as engaged students do, feel, and think (Handelsman et al., 2010). The authors of the original instrument have categorized the items into four categories that define how engaged a student is.

The first category, dubbed *skills engagement*, contains nine items demonstrating student engagement through skill practice. Items included "Staying up on the readings" and "Doing all the homework problems."

*Emotional engagement* is the second category, which has five items. Students' emotional involvement with the course is represented. Items such as "Finding ways to make the course material relevant to my life" and "Thinking about the course between class meetings."

The third category, *participation/interaction engagement*, consists of six items. The items measure student engagement through class participation and interactions with instructors and other students. Items included "Participating actively in small-group discussions" and "Asking questions when I do not understand the instructor."

The fourth category, *performance engagement*, comprises three items representing student participation in the classroom through performance levels. Items included "Helping fellow students" and "Being confident that I can learn and do well in the class."

The text above only shows two examples for each category; all items are listed in Table 6. below:

Table 6. The Student Course Engagement Questionnaire

#	Item	Response (1–5)				
		Less like me		Neutral	More like me	
1	Raising my hand in class	1	2	3	4	5
2	Participating actively in small group discussions	1	2	3	4	5
3	Asking questions when I do not understand the instructor	1	2	3	4	5
4	Doing all the homework problems	1	2	3	4	5
5	Coming to class every day	1	2	3	4	5
6	Asking the teacher to review assignments or tests	1	2	3	4	5
7	Thinking about the course between class meetings	1	2	3	4	5
8	Finding ways to make the course interesting to me	1	2	3	4	5
9	Taking good notes in class	1	2	3	4	5
10	Looking over class notes between classes	1	2	3	4	5
11	Really desire to learn the material	1	2	3	4	5
12	Being confident that I can learn and do well in the class	1	2	3	4	5
13	Putting forth effort	1	2	3	4	5
14	Being organized	1	2	3	4	5
15	Getting a good grade	1	2	3	4	5
16	Doing well on the tests/quizzes	1	2	3	4	5
17	Staying up on the readings	1	2	3	4	5
18	Having fun in class	1	2	3	4	5
19	Helping fellow students	1	2	3	4	5
20	Making sure to study on a regular basis	1	2	3	4	5
21	Finding ways to make the course material relevant to my life	1	2	3	4	5



22	Applying course material to my life	1	2	3	4	5
23	Listening carefully in class	1	2	3	4	5

Students read the following instructions after consenting to participate, then completed the SCEQ:

*This questionnaire contains several statements about students' engagement towards learning. You will be asked what you think about these statements and how they apply to you. There are no 'right' or 'wrong' answers.*

*Suppose the statement is "more like you," choose a response of 4. If it is "much more like you," choose a response of 5.*

*If a statement is "less like me," choose a response of 2. If it is "much less like me," select a response of 1.*

*If there is no preference, i.e., neither "like me" nor "not like me," then choose a response of 3.*

Lastly, the post-questionnaire contains a *Net promoter score* (NPS) question, asking the participant: "How likely are you to recommend uniLeague to friends or colleagues?". The group wants to include the NPS when evaluating if uniLeague should be further developed or not. We will come back to NPS in section 5.2 *Measure the engagement* below.

### 3.3.6 Questionnaire quality

Numerous factors can impair the response to a computer questionnaire, such as the SCEQ we used. In this section, we will present some of the factors that we believe may have affected the value of our data.

#### 3.3.6.1 Self-reported data

The group used self-reported data to figure out how engaged students were in the class. However, the reliability of this kind of data might be harmed by people not being able to accurately reflect on their engagement in class (Bowman, 2011).

#### 3.3.6.2 Social desirability bias

Similarly, the students might be affected by *Social Desirability Bias* (SDB) and paint themselves as a "more perfect" student than they are. For instance, it might take the form of over-reporting socially desirable behavior, such as "doing all the homework problems" and "coming to class every day" (Bowman, 2022; Krumpal, 2011).

#### 3.3.6.3 Vague language in the instrument

The instrument uses relative language, such as "good" and "do well." Students might have different definitions of what it means to "get a good grade" in a class or "do well" on a quiz and respond based on their definitions (Bowman, 2011).

#### 3.3.6.4 No interviewer present

As de Leeuw, How, and Dillman (2012) argue in their book *International Handbook of Survey Methodology*, the absence of an interviewer to motivate respondents to complete the interview may result in increased break-off rates. Whether this occurred with our survey is unknown because Microsoft Forms does not track incomplete questionnaires. However, it appears likely, as only 12-13 of 26 eligible students responded to the questionnaires.

### 3.3.7 Improving questionnaire quality

To combat the social desirability bias, the group kept the questionnaire anonymous and reminded the respondent that there were no right or wrong answers in the questionnaire's introduction.

The previous section has shown the procedure behind the 23-item SCEQ by Handelsman et al. used to measure the engagement before and after using uniLeague in class. It has been explained why the group chose this instrument instead of others and how it was distributed among students.

In the following section, the group presents the methods to ensure the sustainability of uniLeague.

## 3.4 Ensuring Sustainability

Lastly, this section will show the methods used to answer the final problem area, *ensure sustainability*.

### 3.4.1 Choosing a green web host

The theory section 2.5.1.1 *Green hosting* mentions that hosting the project would be the most obvious thing that can be readily done for a more sustainable website. The Green Web Foundation's Green Hosting Directory was used to look for hosting companies that could demonstrate their green claims.<sup>10</sup> While the directory lists 403 green hosting companies in 29 countries, only the six companies in Norway were examined.

Table 7 below displays the companies and the URL to the company's web page—additionally, a note about what was found when visiting the website.

---

<sup>10</sup> See <https://www.thegreenwebfoundation.org/directory/>

Table 7. The companies considered for hosting uniLeague

Company	URL	Note	Chosen?
Nexthop AS	<a href="https://nexthop.no/">https://nexthop.no/</a>	It appears not to support MERN-stack websites	X
Servebolt	<a href="https://servebolt.com/">https://servebolt.com/</a>	It appears to support only WordPress-powered websites.	X
ZETTA.IO TECHNOLOGY AS	<a href="https://www.zetta.io/en/">https://www.zetta.io/en/</a>	A complete infrastructure-as-a-service platform for the production of IT services seems excessive. It is unknown whether the host is capable of hosting MERN projects.	X
Blix Solutions AS	<a href="https://www.blix.com/">https://www.blix.com/</a>	Their website is sparse and very business-oriented. As a result, getting started was difficult.	X
Sircon Norge AS	<a href="https://sircon.no/">https://sircon.no/</a>	It appears to support only WordPress-powered websites.	X
SYSE AS	<a href="https://www.syse.no/">https://www.syse.no/</a>	It appears to support only WordPress-powered websites.	X

ServeBolt seemed like a suitable host as they had a strong stance on sustainability, and the UN Sustainable Development Goal 13: Climate Action, in line with our problem area, *ensure sustainability* (Servebolt AS, n.d.). After a meeting with the sales representatives at ServeBolt, it was discovered that ServeBolt did not support the hosting of MERN-stack projects and moved on.

Google was used to look for additional green hosts. "Green hosting for MERN stack," "green hosting node," and "host node.js app green host" were used as search terms. Digital Oceans' Twitter account was discovered, claiming that its data centers are powered entirely by 100% renewable energy (DigitalOcean, 2020). The GitHub Student Developer Pack was used to obtain a Droplet (defined in section 3.2.4) and a domain name from *Name.com*<sup>11</sup>.

### 3.4.2 Configuring the Content Delivery Network

As described in 2.5.1.2 *Content delivery network*, a CDN refers to a group of geographically distributed servers that collaborates quickly to provide internet resources. The initial steps to configure Cloudflare as a CDN are:

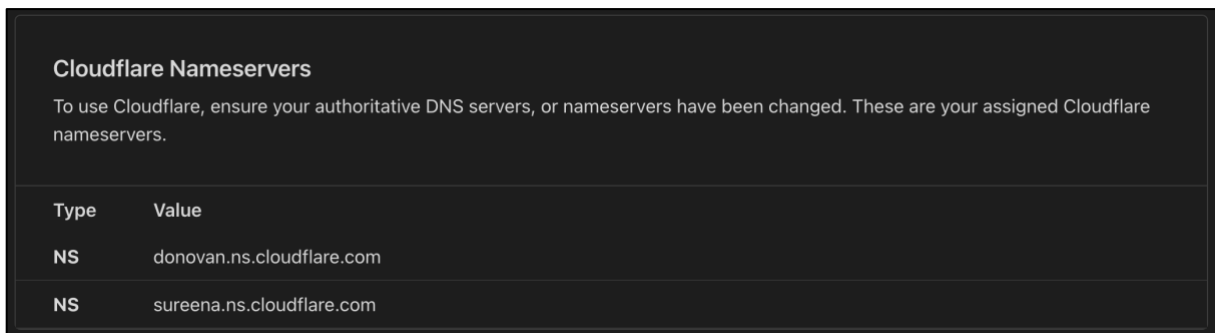
1. **Nameservers**, point the domain name to Cloudflare's nameservers.
2. **DNS**, add DigitalOcean Droplet IP address to Cloudflare's DNS

---

<sup>11</sup> See <https://www.name.com/>

To point the domain name “unileague.games” to Cloudflare's nameservers, the following steps were taken: check the assigned nameservers found on the Cloudflare dashboard; see Figure 10. Go to the domain registrar and update the nameservers; see Figure 11.

Lastly, to add the DigitalOcean droplet IP address and the domain name, and www as A-type, see Figure 12.

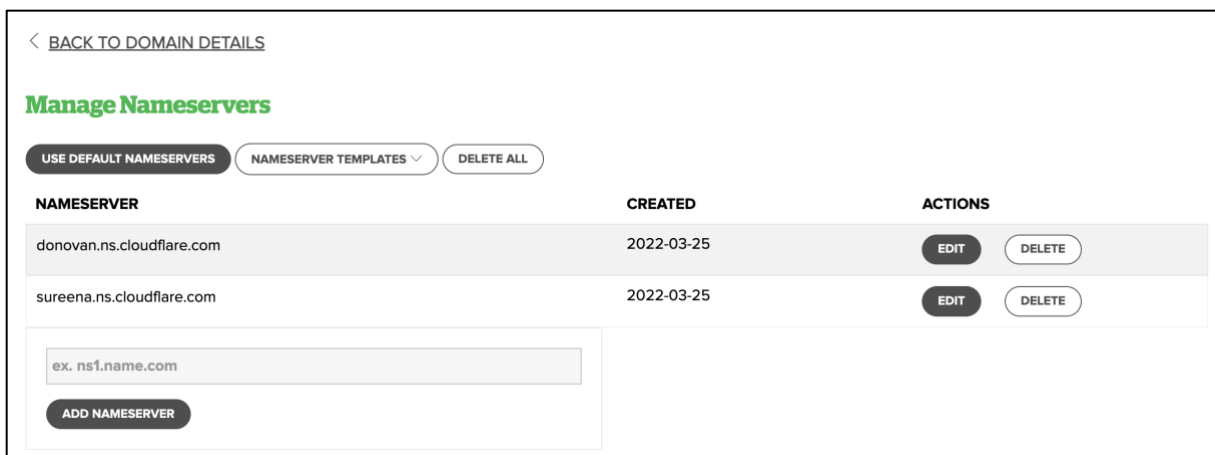


**Cloudflare Nameservers**

To use Cloudflare, ensure your authoritative DNS servers, or nameservers have been changed. These are your assigned Cloudflare nameservers.

Type	Value
NS	donovan.ns.cloudflare.com
NS	sureena.ns.cloudflare.com

Figure 10. Cloudflare nameservers assigned to the "uniLeague.games" domain



< [BACK TO DOMAIN DETAILS](#)

### Manage Nameservers

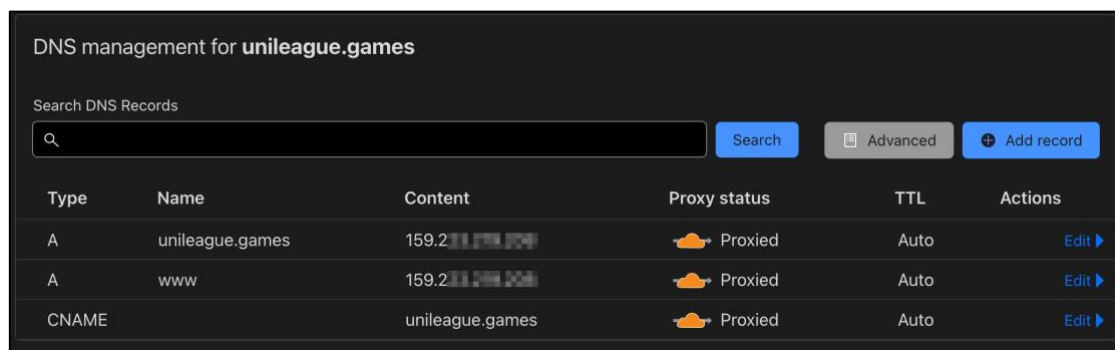
USE DEFAULT NAMESERVERS NAMESERVER TEMPLATES DELETED ALL

NAMESERVER	CREATED	ACTIONS
donovan.ns.cloudflare.com	2022-03-25	EDIT DELETE
sureena.ns.cloudflare.com	2022-03-25	EDIT DELETE

ex. ns1.name.com

ADD NAMESERVER

Figure 11. Added Cloudflare nameservers to the "uniLeague.games" domain



DNS management for **unileague.games**

Search DNS Records

Search Advanced Add record

Type	Name	Content	Proxy status	TTL	Actions
A	unileague.games	159.2 [REDACTED]	Proxied	Auto	Edit
A	www	159.2 [REDACTED]	Proxied	Auto	Edit
CNAME	unileague.games		Proxied	Auto	Edit

Figure 12. DNS management for uniLeague.games (IP has been censored)

To see the statistics of cached data and traffic, see section 4.5.2 *Using Content Delivery Network*.

### 3.4.3 Caching information

To reduce calls to the back-end, we utilized `sessionStorage`. `SessionStorage` stores data in the browser and is deleted between browser sessions (Mozilla Developers, 2019). The code will check if the data is stored whenever a component is accessed, like the leaderboard. If the data is stored, it will use the data stored in the `sessionStorage` property. If not, it will call the back-end for data and store it in the `sessionStorage` property.

```
fetchLeaderboard = async () => {
  if (sessionStorage.getItem('courses') && sessionStorage.getItem('semesterLeaderBoard')) {
    this.setState({
      isLoading: false,
      courses: JSON.parse(sessionStorage.getItem('courses')),
      semesterLeaderBoard: JSON.parse(sessionStorage.getItem('semesterLeaderBoard'))
    })
  } else {
    try {
      const res = await getLeaderboard();

      const courses = res.data.getUserSpecific;
      const semesterLeaderBoard = res.data.studyProgrammeData;
      sessionStorage.setItem('courses', JSON.stringify(courses));
      sessionStorage.setItem('semesterLeaderBoard', JSON.stringify(semesterLeaderBoard));

      this.setState({
        courses,
        semesterLeaderBoard,
        isLoading: false
      })
    } catch (error) {
      this.setState({
        error: error.response.error.message,
        isLoading: true
      });
    }
  }
}
```

Figure 13. Code for caching data from the back-end.

Figure 13 illustrates an excerpt from "LeaderboardHOC.jsx," which checks `sessionStorage` for the presence of the keywords `courses` and `semesterLeaderBoard`. If it does, it will set the application's state to those values; if not, it will attempt to retrieve the data via an API call. The data is then stored in `sessionStorage`, and the application's state is set to the values retrieved from the back-end.

### 3.4.4 Optimizing imagery

We can minimize the image file size to make uniLeague more sustainable. The image optimization process begins with exporting the desired screenshots from Figma in the recommended sizes for "mockuPhone" (File type: PNG, Width: 1170px, height: auto).

MockuPhone<sup>12</sup> is an online tool that enhances the realism of our images by simulating an actual phone.

We need to remove the transparent pixels surrounding our images on the mockuPhone. By opening the image in Photoshop and clicking "Image," then "Trim." we can remove the transparent pixels. Then, using Photoshop, we export the image with a width of 358px. It is acceptable because the images will never be displayed at a size greater than this.

The exported images are then uploaded to TinyPNG<sup>13</sup>, a free online image compressor, where they are compressed according to Tom Greenwood's recommendations. (Greenwood, 2021, p. 44) There are no settings available for this tool.

Finally, we convert our images to more contemporary file formats like WebP and AVIF. We use the converter on FreeConvert<sup>14</sup> to convert our PNG files to WebP. Due to the inability of this service to convert PNG to AVIF, we use the service AVIF.io<sup>15</sup> to convert the images from PNG to AVIF.

Section 4.5.4 *Using optimized imagery* in the Results chapter demonstrates the file savings of optimizing uniLeague's images.

### 3.4.5 Optimizing typography

As uniLeague is a part of NTNU, we decided to use NTNU's brand font, Open Sans, to match NTNU's style guide. While Open Sans is not a system font, the amount of data transferred will be reduced by optimizing typography, making uniLeague more sustainable.

The optimization process begins with the download of the required fonts. In our case, we use Google Fonts to download "Open Sans-Regular" and "Open-Sans-Bold."<sup>16</sup> These are large TrueType font files (.ttf).

Second, both font files are subset. Subsetting removes glyphs that will never be used on the page (See section 4.5.5 *Using optimized typography*). For instance, we omit the letters "Ä"

---

<sup>12</sup> See <https://mockuphone.com/> for MockuPhone.

<sup>13</sup> See <https://tinypng.com/> for TinyPNG compression tool.

<sup>14</sup> See <https://www.freeconvert.com/> for the image conversion tool.

<sup>15</sup> See <https://avif.io/> for image conversion tool.

<sup>16</sup> See <https://fonts.google.com/specimen/Open+Sans> for Open Sans font.

and "Ö" because uniLeague will always use the English or Norwegian alphabet. As a result, the Swedish alphabet (and many others) is unneeded and increases the size of our file.

To subset the font files, we use the "Font Subsetter" tool from [everythingfonts.com](https://everythingfonts.com)<sup>17</sup> with the following settings: basic latin, uppercase, lowercase, numbers, and include these single characters ("Æ Ø Å æ ø å"). The remaining options are left unchecked.

Lastly, we convert the TrueType font file to a WOFF2 file as a third step. We can upload the .ttf file to Cloudconvert's website<sup>18</sup> and download the font as a WOFF2 file. As a result, we now have a small font file that we can use as normal. We will examine file size savings in section 4.5.5 of the Results chapter.

We chose to convert our files exclusively to WOFF2 because, according to [caniuse.com](https://caniuse.com)<sup>19</sup>, this font file format is supported by 93.74% of modern browsers. Conversion to other file formats, such as WOFF1, was thus deemed unnecessary.

Lastly, using "src: local()" in CSS, we first look for the file on the machine locally. If it is not found, we download the optimized files mentioned above; otherwise, we can use the local file (See lines 5 and 15 in Figure 14 below).



```
1 @font-face {
2   font-display: swap;
3   font-family: "Open Sans";
4   font-weight: 700;
5   src:
6     local("OpenSans-Bold"),
7     local("Open Sans Bold"),
8     url("../assets/OpenSans-Bold-subset.woff2");
9 }
10
11 @font-face {
12   font-display: swap;
13   font-family: "Open Sans";
14   font-weight: 400;
15   src:
16     local("OpenSans-Regular"),
17     local("Open Sans Regular"),
18     local("Open Sans") url("../assets/OpenSans-Regular-subset.woff2");
19 }
```

Figure 14. CSS code snippet. The CSS looks for a local font file before downloading it.

---

<sup>17</sup> See <https://everythingfonts.com/subsetter> for "Font Subsetter" tool.

<sup>18</sup> <https://cloudconvert.com/>

<sup>19</sup> <https://caniuse.com/?search=woff2>

### 3.4.6 Optimizing bundle size

Using the tool “BundlePhobia”<sup>20</sup> by Shubham Kanodia, the group has measured the size of each “npm package” used in the code (Refer to npm, Inc., 2019). The tool also recommends smaller packages. When a more petite package was recommended, the group minimized the bundle size by replacing the current package with the smaller one.

Also, sometimes a package was defined as unnecessary and was instead coded by us. For example, initially, we used a React package for loading components displaying a spinning wheel. However, the same can be coded with plain HTML and CSS, which has smaller file sizes and is thereby more sustainable.

By following the *Analyzing the Bundle Size* article by Cherouvim (2019), we examined bundle size before and after adding or removing npm packages using the "Source map explorer"<sup>21</sup> tool. 4.5.6 *Using optimized bundle size*, demonstrates the results of removing unneeded npm packages using the Source map explorer tool.

#### 3.4.6.1 Optimizing iconography

We use the *Material Icons* by Google Fonts for uniLeague. Developers can incorporate these icons in a variety of ways. Each approach has a different file size and number of external resource requests. As a result, it is worthwhile to investigate various approaches and select the most appropriate one.

In Table 8, we explore the different approaches.

Table 8. Approaches for sustainable iconography.

Approach	Approximate file size	Note
An icon font for the web	42KB (WOFF2)	The simplest method for including material icons in web projects
Individual SVG files compressed by gzip	62KB	Inefficient to scale, but small file sizes
material-design-icons npm package	13KB	Additionally, the styled components npm package must be installed.
SVG sprites	Depending on the number of icons	Inefficient to scale, but small file sizes

At first, uniLeague relied on the material-design-icons npm package<sup>22</sup>. However, after learning about SVG sprites, we wanted to investigate that possibility. We will demonstrate in

<sup>20</sup> See <https://bundlephobia.com/>

<sup>21</sup> See <https://www.npmjs.com/package/source-map-explorer> for installation and documentation

<sup>22</sup> See <https://www.npmjs.com/package/material-design-icons> for installation and documentation.



this section how we created the smallest – and most sustainable – iconography solution possible.

Creating the SVG sprite begins with downloading each uniLeague's SVG files from the Google Material Design Icons website (refer to Google Fonts, n.d.). Then, we can use the "SVGOMG"<sup>23</sup> compression tool to compress our SVG files individually. We left the tool's default settings alone but increased the "perfection" option to 1 to keep smooth curves on all icons.

The compressed SVG icons are then combined into a single SVG-sprite using svgsprit.es<sup>24</sup>. The tool automatically merges all SVGs into a single file, which we can download and use in our code. We also retained the default settings for this tool. The results of the SVG compression can be found in section 4.5.6.1 *Using optimized iconography*.

### 3.4.7 Optimizing code splitting

Practically we use the “lazy()” function to import the code we want to split. Now the code is only imported when it needs to be rendered. See Figure 15 below.

---

<sup>23</sup> <https://jakearchibald.github.io/svgomg/>

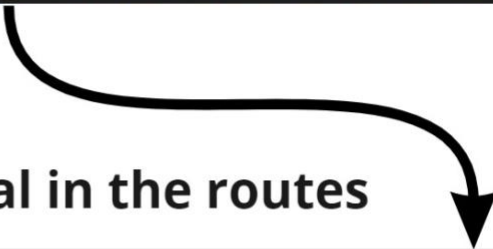
<sup>24</sup> <https://svgsprit.es/>

## Use lazy() to import the code

```

23 const About = lazy(() => import('./components/About/About'));
24 const Denied = lazy(() => import('./components/Error/Denied'));
25 const Footer = lazy(() => import('./components/Footer/Footer'));
26 const Leaderboard = lazy(() => import('./components/Leaderboard/Leaderboard'));
27 const Login = lazy(() => import('./components/Login/Login'));
28 const MyResults = lazy(() => import('./components/MyResults/MyResults'));
29 const NotFound = lazy(() => import('./components/Error/NotFound'));
30 const Settings = lazy(() => import('./components/Settings/Settings'));
31 const WorkProgress = lazy(() => import('./components/WIP/WorkProgress'));

```



## Use the code as normal in the routes

```

<Route path='/about/*' element={<About />} exact />
<Route path='/developer' element={<Developer />} exact />
<Route path='/help' element={<WorkProgress />} exact />

```

Figure 15. Code snippet displaying code splitting by using the lazy() function

### 3.4.8 Bringing information to the front

By adding the “Placement: x” label text underneath the course code and course name, the user will get their ranking in a course on the home screen. Bringing information to the front can reduce the number of times a user will navigate to a specific course page, which will reduce the number of times the back-end server is queried, data is transferred, and battery is consumed, if on mobile devices.

Figure 16 shows a code snippet of how we brought information forward.

```

<Link className={`card ${disabledLink ? 'disabled-link' : ''}`} to={link} >
  <div>
    <h3>{courseCode} {fullCourseName} </h3>
    {rank ? <p>Placement: {rank}</p> : null}
  </div>
</Link>

```

Figure 16. Code snippet displaying the placement of a user in a card

## 3.5 Project management

The project group consists of three members. This section details the project group's organization and distribution of work and the collaboration tools used.

The project group has spent three years at NTNU getting to know one another's workflows through collaboration on several previous projects. The group developed rules that worked in the past and thus played a role in this project. These internal guidelines are primarily focused on practical and frequent communication. One must always keep the other members informed of one's work and process status. Being up to date on others' work is critical for project flow, preventing multiple people from working on the same thing and wasting time and resources. Along with daily updates via Discord, a VoIP application, weekly meetings have been held to maintain communication.

We communicated with external actors via e-mail, including our tutor, whom we met digitally every fortnight, and those invited to test prototypes (See 3.1.5.6 *Finding participants*). To ensure transparency in communication, we added all internal group members to the Carbon Copy line of each e-mail.

Documents and other files were shared via OneDrive, enabling real-time editing, similar to the prototyping tool Figma used to create the prototype. Microsoft Word was used to format and write the report.

### 3.5.1 Tools utilized

#### 3.5.1.1 *Distributing work with Microsoft Teams*

To organize and distribute the work, Microsoft Teams was used in the form of Kanban boards. We used Kanban boards to track what needed to be done, what was done, and what was finished. Simultaneously, the Kanban board kept track of who was assigned tasks and participated in activities, see Figure 17 below.

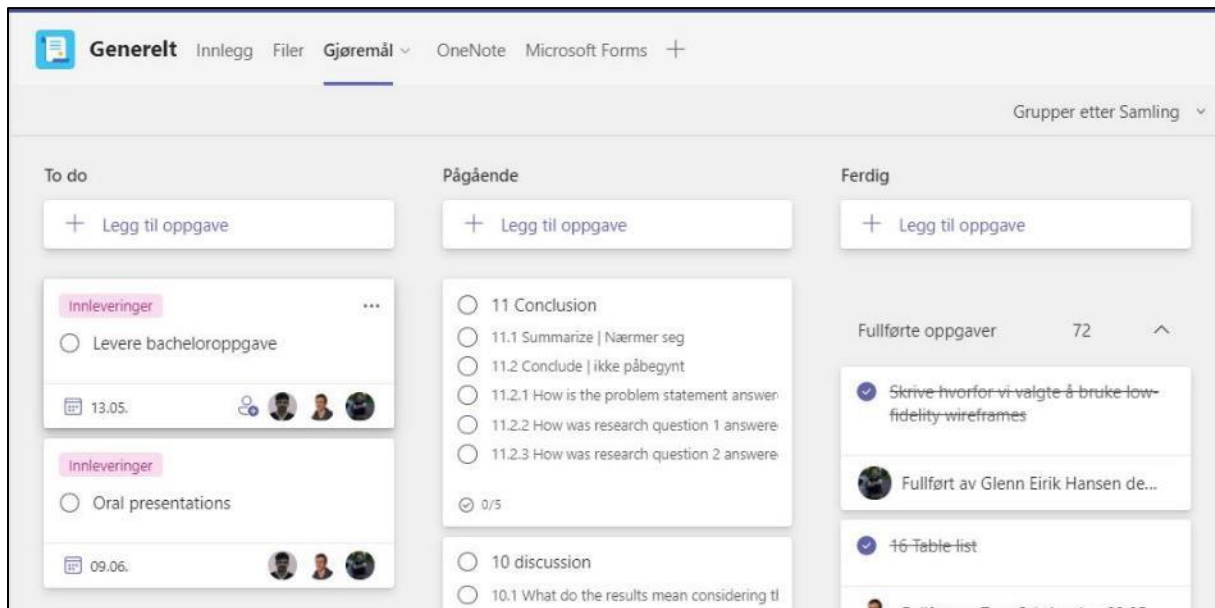


Figure 17. Kanban Board inside Microsoft Teams with tasks.

### 3.5.1.2 Visualizing project management with GANNT

We used a GANNT diagram to visualize the project's major phases, including research, design, development, and writing. The GANNT diagram indicates whether we were meeting or missing our internal deadline. See Figure 18 below.

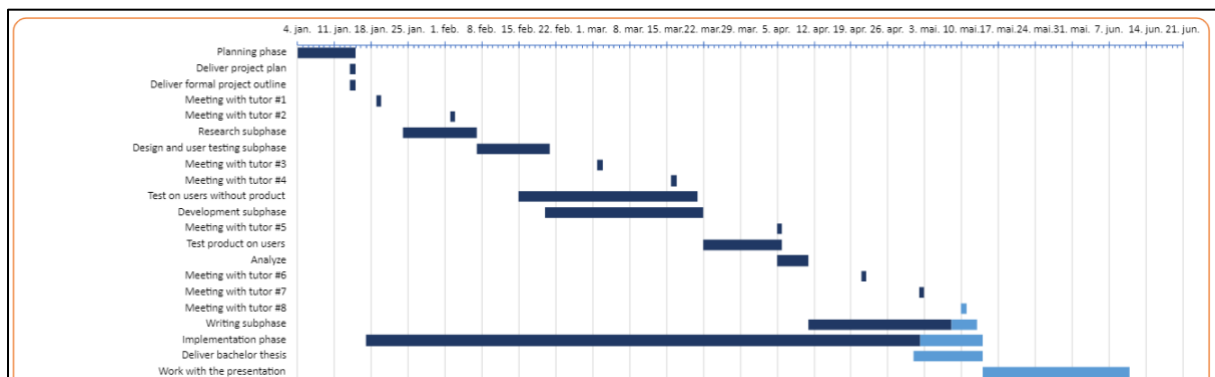


Figure 18. GANNT diagram displaying the phases and deadlines of the project.

### 3.5.1.3 Storing code on GitHub

The solution's code is stored on GitHub, a version control system. GitHub enables remote collaboration and code sharing. We decided to create an organization in GitHub to create two repositories and connect them.

## 4 Results

This chapter will describe the most critical findings from the design, development, study, and sustainability measures. The chapter will cover the same three problem areas in which the project is divided: *design and develop a web application*, *measure the engagement*, and *ensure sustainability*.

We first consider the web application created and the results of the design and development methods. This section will show the result from the first problem area, *design and develop a web application*.

### 4.1 uniLeague – Web Application

The results displayed here are a result of sections 3.1 *Designing the web application* and 3.2 *Developing the web application*. The result is *Single Page Application (SPA)* called “uniLeague” and is created with the MERN-stack (See section 2.3.8 *Using the MERN-stack*). From section 1.2 *Desiderata*, ten desiderata were mentioned, categorized into five sections. Following are five sections displaying the solution to these desiderata, and lastly, two sections showing the web application.

#### 4.1.1 Track student and class progression

The product owner's first and most critical feature is the ability to track their students' progress through a semester, year, or even a study program. The solution was a leaderboard showing the students' rank, username, score, and the number of quizzes they attended. Figure 19 shows the leaderboard.

Student (2) Full leaderboard				Teacher / Super Admin (2) Full leaderboard			
Rank	Username	Score	Attended	Rank	Username	Score	Attended
1 🏆	nebula	36,692	6	1 🏆	nebula	36,692	6
2 🥈	okoye	31,474	6	2 🥈	okoye	31,474	6
3 🥉	antman	30,686	6	3 🥉	antman	30,686	6
4	groot	26,479	6	4	groot	26,479	6
5	ironman	24,040	5	5	ironman	24,040	5
6	anonymous	13,918	3	6	hawkeye	13,918	3
7	anonymous	11,765	3	7	peggy	11,765	3
8	anonymous	9,786	3	8	scarletwitch	9,786	3
9	anonymous	9,356	3	9	hulk	9,356	3
10	anonymous	6,720	3	10	blackwidow	6,720	3
11	ikaris	4,588	2	11	ikaris	4,588	2
12	anonymous	4,095	1	12	mantis	4,095	1
13	anonymous	3,706	1	13	loki	3,706	1
14	anonymous	3,273	1	14	captainmarvel	3,273	1
15	anonymous	2,731	1	15	nickfury	2,731	1

Figure 19. Full leaderboard for student and teacher / super admin

### 4.1.2 Visualization

Second, after uploading the files to the web application, the product owner wishes the students to see their progress and position on the leaderboard. The product owner wishes to maintain the anonymity of everyone outside the top five on the leaderboard. The product owner hopes that anonymity will keep students motivated, even if students are near the bottom of the leaderboard.

Figure 20 shows a student's quiz performance and how students outside the top five have been anonymized except for the user (Ikaris).

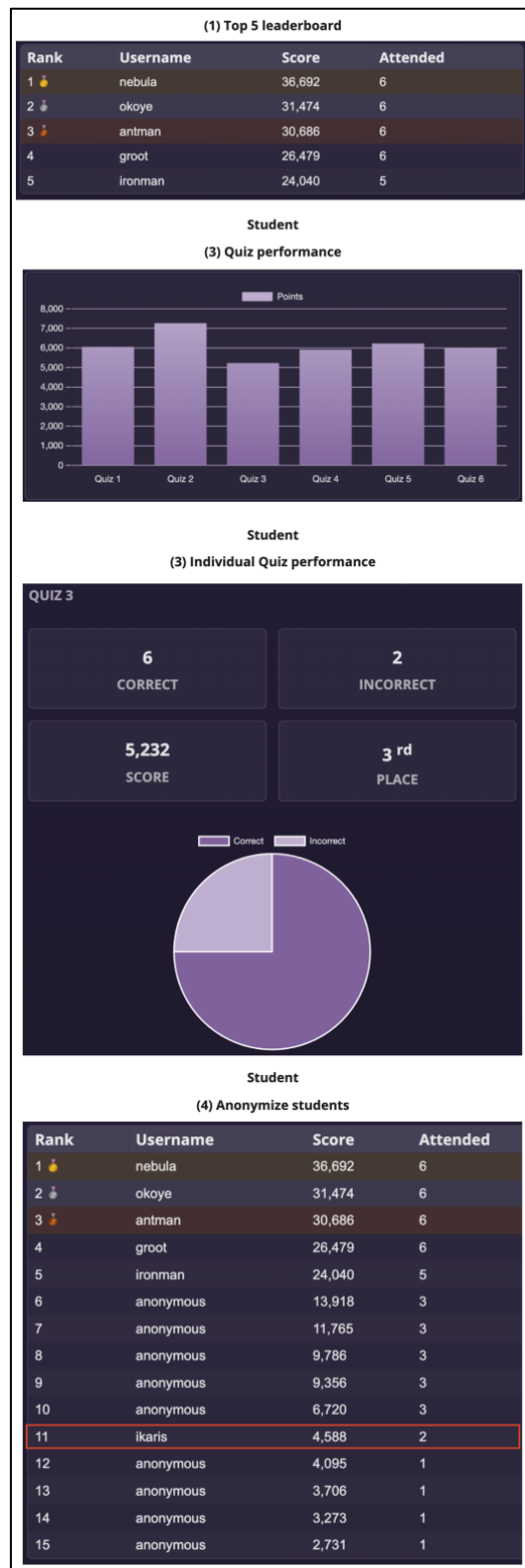


Figure 20. Shows top five leaderboard, a bar chart displaying a user's performance, a pie chart displaying individual quiz performance, and an anonymized leaderboard

### 4.1.3 Summarization of scores

Thirdly, one of the areas that present difficulties is the summarization of scores. Currently, this is accomplished manually by the product owner or a student assistant. As a result, the product owner wants this process to be automated, thus eliminating the possibility of human error.

Figure 21 shows a snippet of the Excel file the product owner utilizes to add the scores together and how they display the results on a lecture slide.

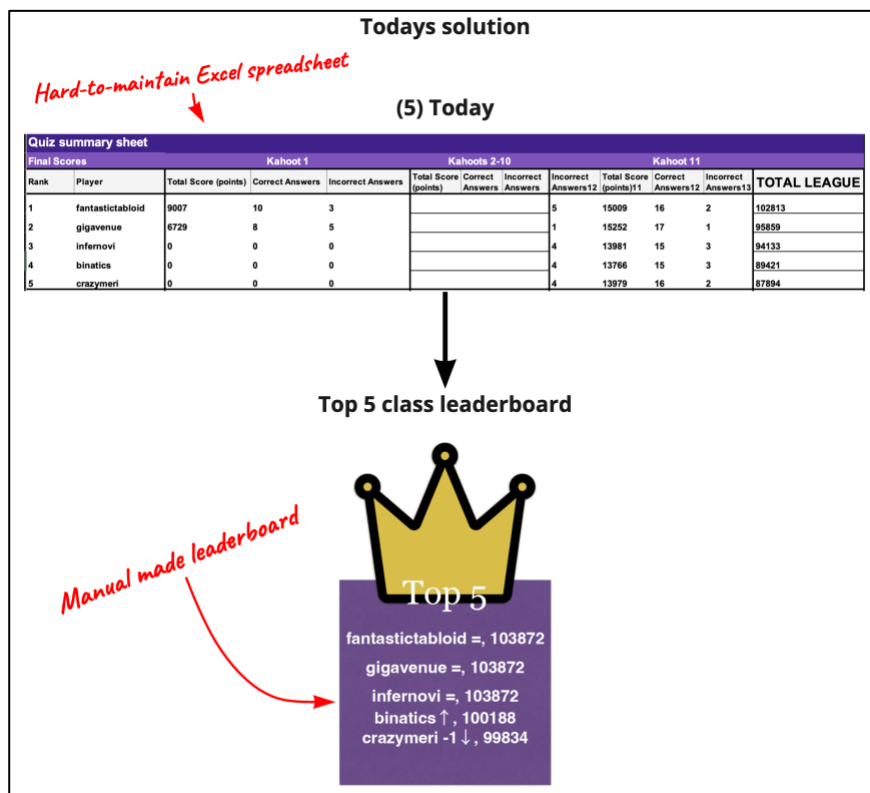


Figure 21. Shows how the product owner summarizes and displays the results

Figure 22 shows how the product owner can upload the Excel file they download from Kahoot! to uniLeague. Once uploaded, the scores will be summarized and displayed on the leaderboard.



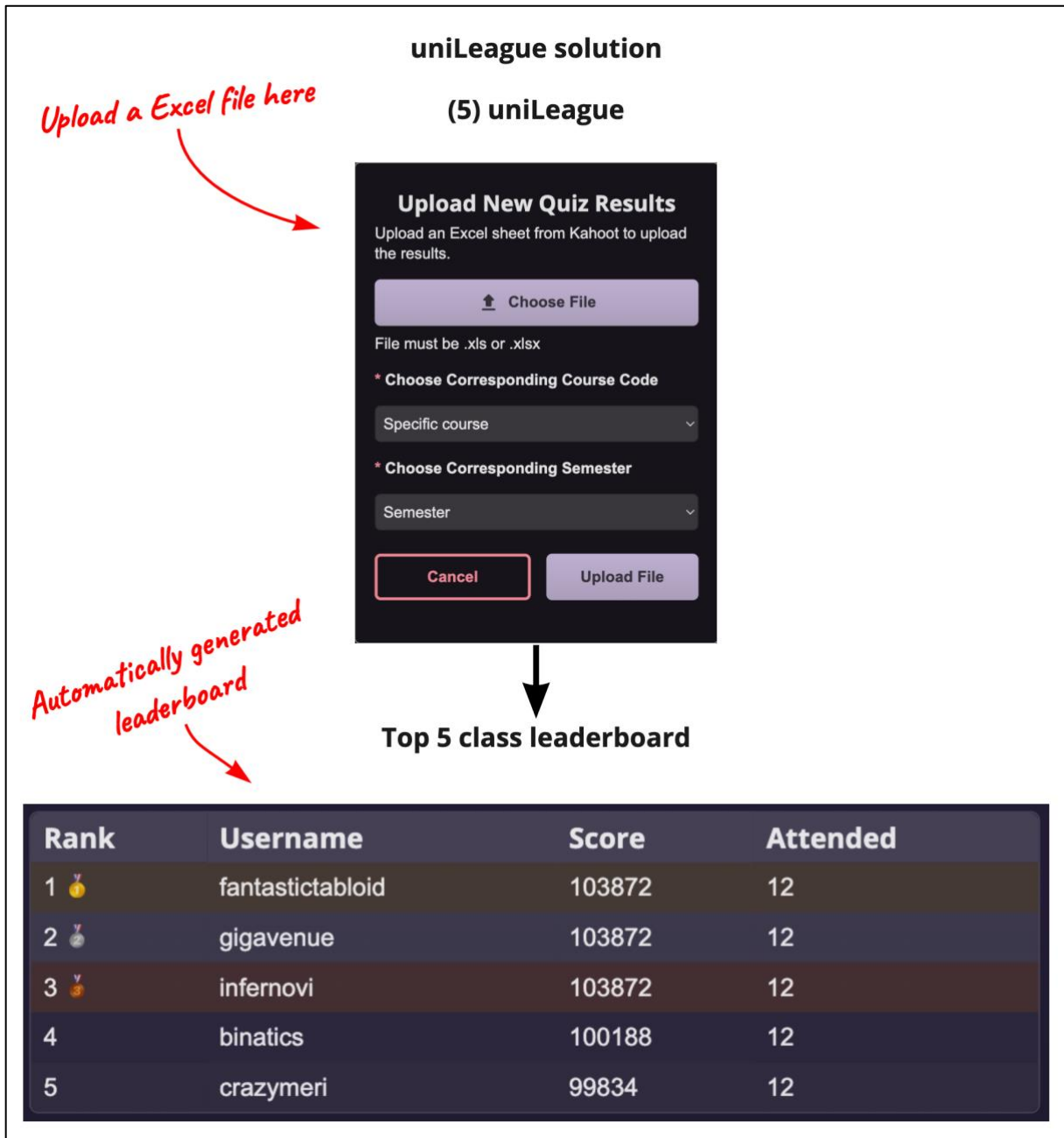


Figure 22. UI components show how the product owner can upload a file to uniLeague

### 4.1.4 Scalability

The following four wishes are that the product owner wishes the application to be scalable. With "to be scalable", the product owner means they want the ability to integrate other activities besides Kahoot, like lecture covers and Mentimeter. The application should handle several hundred students, and the product owner should be able to add and remove users. The application should also be able to be further developed by the product owner.

Figure 23 shows a snippet of the code that accepts different “activities,” such as Mentimeter, and how the database will look when there are several activities. Because of limitations, this feature has not been fully implemented and is therefore only limited to kahoots.

**(6) Activities**  
**Code snippet**

```
1  const name = 'kahoot';
2  const variant = 'quiz';
3
4  {...}
5
6  // Array with activities to be saved
7  const activityIds = [];
8
9  course.activities.forEach((kahoot) => {
10   if (kahoot.name === name && kahoot.variant === variant) {
11     const [kahoots] = kahoot.sources;
12     activityIds.push(kahoots);
13   }
14 });
```

*Defaults to Kahoot*

**Database**

```
_id: ObjectId("6230d63c2f090883b30f1850")
code: "IDG2100"
courseId: "IDG2100_f2019"
name: "Full stack Web Development"
credits: 7.5
activities: Array
  0: Object
    name: "kahoot"
    variant: "quiz"
    sources: Array
      0: ObjectId("62432797e26ba33ff95ff603")
      1: ObjectId("624327f3e26ba33ff95ff650")
      _id: ObjectId("6230d63c2f090883b30f1851")
  1: Object
    name: "keynote"
    variant: "cover"
    sources: Array
      _id: ObjectId("6230d63c2f090883b30f1852")
createdAt: 2022-03-15T18:09:00.366+00:00
updatedAt: 2022-03-30T11:26:25.871+00:00
__v: 0
```

*Kahoot activity entries*

Figure 23. Code shows that different activities can be accepted

### 4.1.5 Sharing

Lastly, the product owner wishes the students to have the ability to share their results with others. However, this has not been solved because of time constraints and being the least important desiderata.

### 4.1.6 Student view

For the web application, it was essential to differentiate between a student and a teacher/administrator. This first section will show how students can log in, view their course performance, and see their position on the leaderboard. See Figure 24.



Figure 24. UI components show how a student can log in and see their quiz performance

### 4.1.7 Teacher & admin view

Lastly, this section will show how a teacher/administrator can log in to the application, view the leaderboard, and upload a new quiz to the course. See Figure 25.

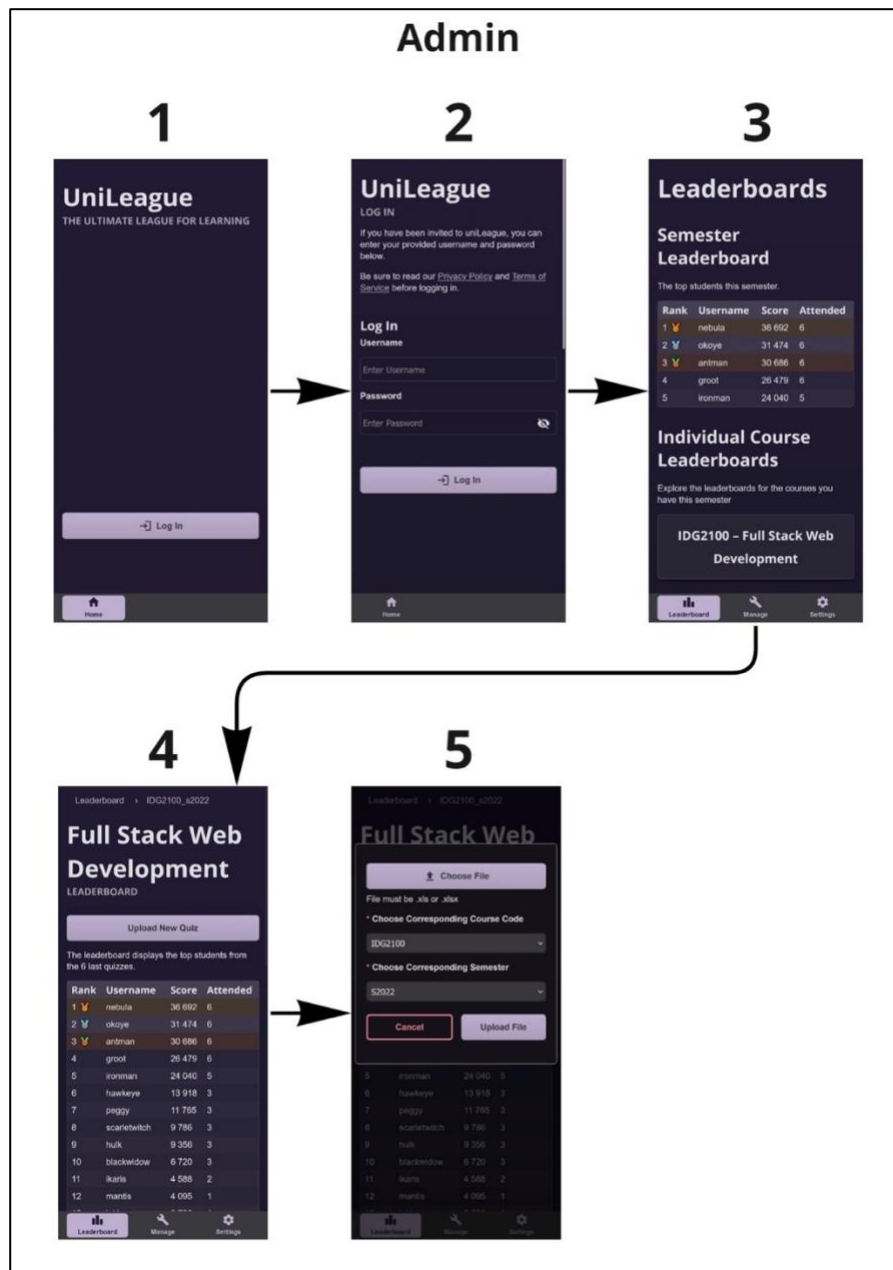


Figure 25. UI components show how a teacher/administrator can log in and upload quiz results to uniLeague

## 4.2 Results from design methods

This section will show the individual results from the first part of the first problem area, *design and develop a web application*.

## 4.2.1 Competitor analysis results

Table 9 lists all competitors and uniLeague, where the capability column has been completed using data from 1.2 Desiderata.

Table 9. Competitor analysis (again)

Capability	uniLeague	Kahoot! EDU	Blackboard Learn	Mentimeter	Quizizz
(1) Track students and class progression	✓	✓	✓	✗	✓
(2) present a graphical representation of quiz results to the students	✓	✓	✓	✗	✗
(3) top five students on a leaderboard	✓	✓	✗	✗	✗
(4) Anonymize names not in the top five leaderboard	✓	✓	✗	✓	✓
(5) Combine reports to reduce human error	✓	✓	✓	✗	✗
(6) Give points for other in-class activities besides the quiz	?	✗	✓	✗	✗
(7) Scale the number of users	✓	✓	✓	✓	✓
(8) Further develop functionality	✓	✗	✗	✗	✗
(9) User management	✓	✓	✓	✗	✓
(10) Sharing results	✗	✓	✗	✓	✓
Price billed annually (as of spring 2022)	Free	\$25/ per educator monthly	N/A	\$10 / \$25 monthly	\$19 per host monthly

Kahoot! EDU appears to be a viable option. The biggest challenge with the current solution used by the product owner is restrictions such as paywall, not being able to develop functionality further, and giving points to in-class activities besides quizzes. A tailor-made application was needed to satisfy the needs mentioned in section 1.2 Desiderata.

## 4.2.2 Wireframing results

Wireframing is used to create a low-fidelity prototype (see 3.1.4 *Creating low-fidelity prototypes*). As section 3.1.2 *Creating wireframes* mentioned, Crazy 8 was used to create wireframes. We first present the results from the first iteration (see Figure 26). After that, we present the results from the second iteration (see Figure 27). The wireframes that were further developed are highlighted in green.

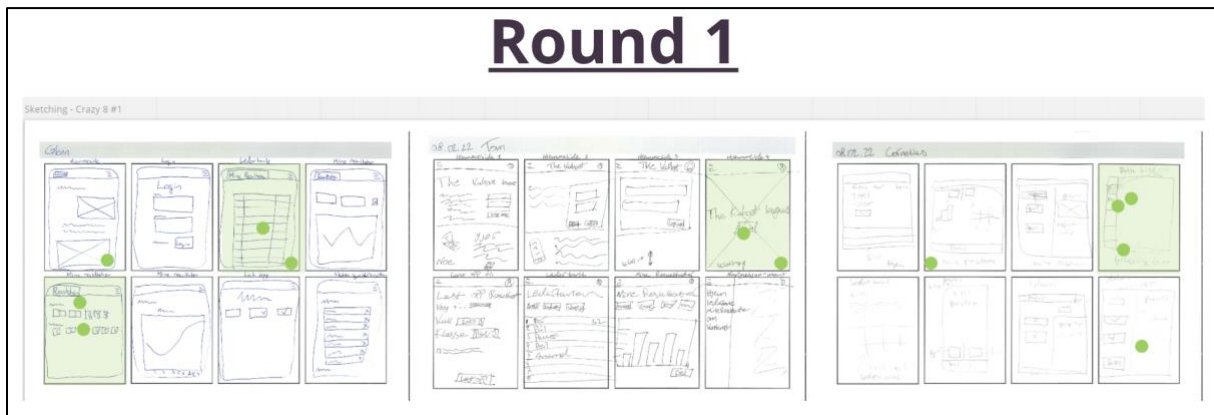


Figure 26. The first iteration of wireframes generated by the Crazy 8 technique

Figure 26 illustrates the outcome of the first round. It shows four light green squares that the group will develop further in round two.

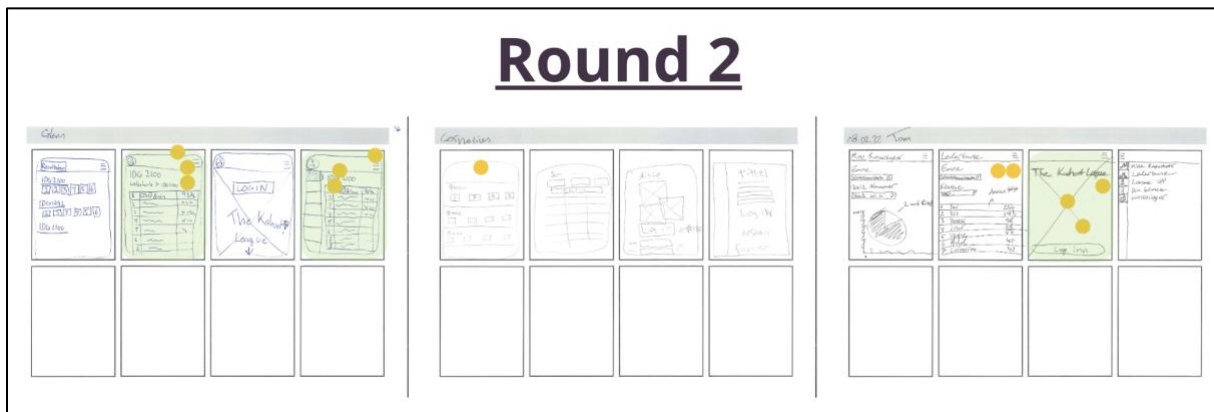


Figure 27. The second iteration of wireframes generated by the Crazy 8 technique

Figure 27 illustrates the outcome of the second round. It shows three squares marked in light green that the group will use for low-fidelity prototyping in Balsamiq (see 3.1.4 *Creating low-fidelity prototypes*).

### 4.2.3 Scenario results

Scenarios are used to create usability tests (see 3.1.5 *Conducting a usability test of the low fidelity prototype*). Section 3.1.3 *Creating scenarios* mentioned that the group used personas to create scenarios with a goal and a result. An example of this is seen in Table 10 below, which illustrates scenarios for each role mentioned in section 2.1.1 *Defining target audiences*. The whole table with all the scenarios is available in *Appendix 3: Scenario*.

Table 10. An excerpt of the scenarios

Who	Context	Story	Event	Intended procedure
<b>Teacher</b>	The teacher has just completed the quiz and has downloaded the results to Excel	As a teacher, I will upload an Excel sheet that contains quiz results from the course I am lecturing on so that I do not have to process the results myself.	Uploading	<ol style="list-style-type: none"> <li>1. Log in</li> <li>2. Upload the document by tapping the "upload" icon in the navigation bar</li> <li>3. After uploading the file, the teacher selects the appropriate year and semester.</li> </ol>
<b>Super admin</b>	Because many first-year students drop out, I would like to remove their users.	As a super admin, I want the opportunity to remove users from a subject so that outdated users do not fill the scoreboards	Users	<ol style="list-style-type: none"> <li>1. Log in</li> <li>2. Go to admin-page</li> <li>3. Go to manage users</li> <li>4. Delete a user</li> </ol>
<b>Student</b>	It is the middle of the semester, and several quizzes have been completed. The student would like to see where they are on the leaderboard throughout the course, regardless of class	As a student, I will be able to see an overview of how I am doing in a subject	Leaderboard	<ol style="list-style-type: none"> <li>1. Log in</li> <li>2. Go to leaderboards</li> <li>3. Choose the subject</li> </ol>

#### 4.2.4 Low-fidelity prototype results

The results of low-fidelity prototyping will be used to create a high-fidelity prototype. As mentioned in section 3.1.4 *Creating low-fidelity prototypes*, the group tested the low-fidelity prototype twice: during the first iteration (see Figure 28) and after the second iteration (see Figure 29).

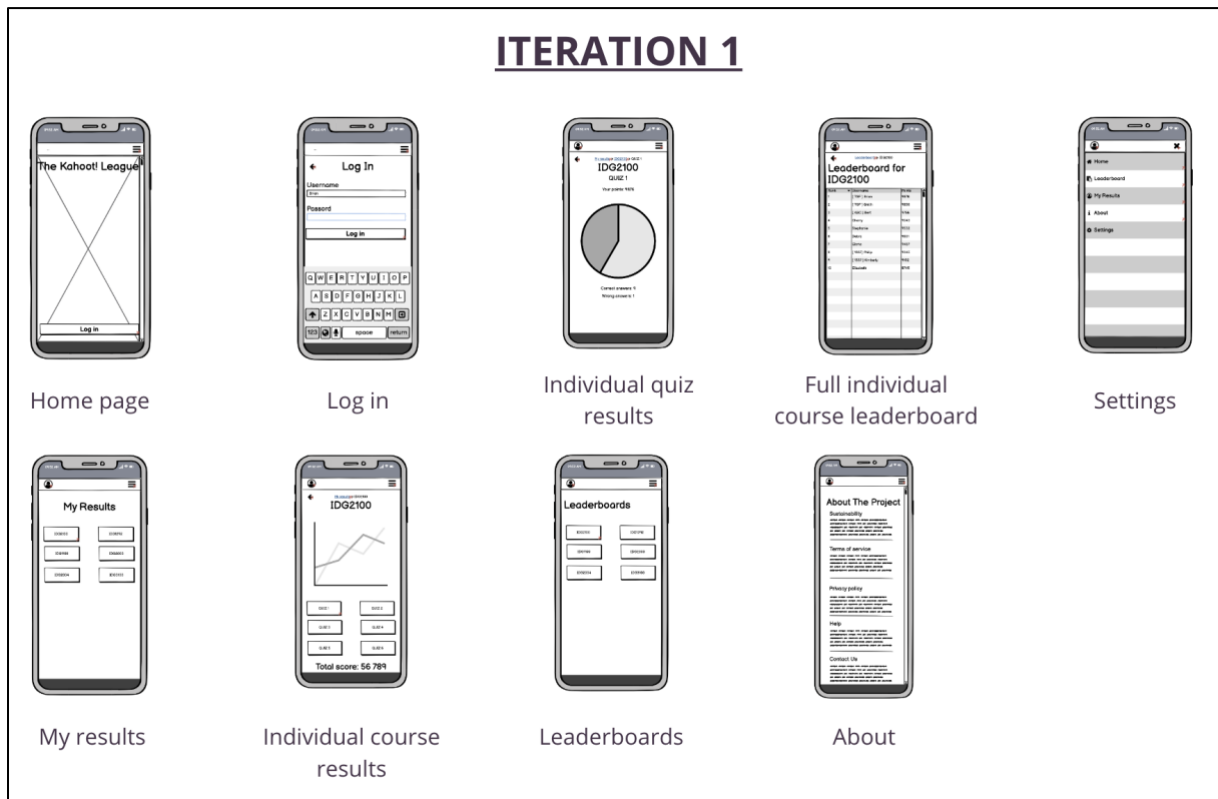


Figure 28. The first iteration of the low-fidelity design was created in Balsamiq.

Wireframes have been converted to a low-fidelity prototype in the first iteration (Figure 28)



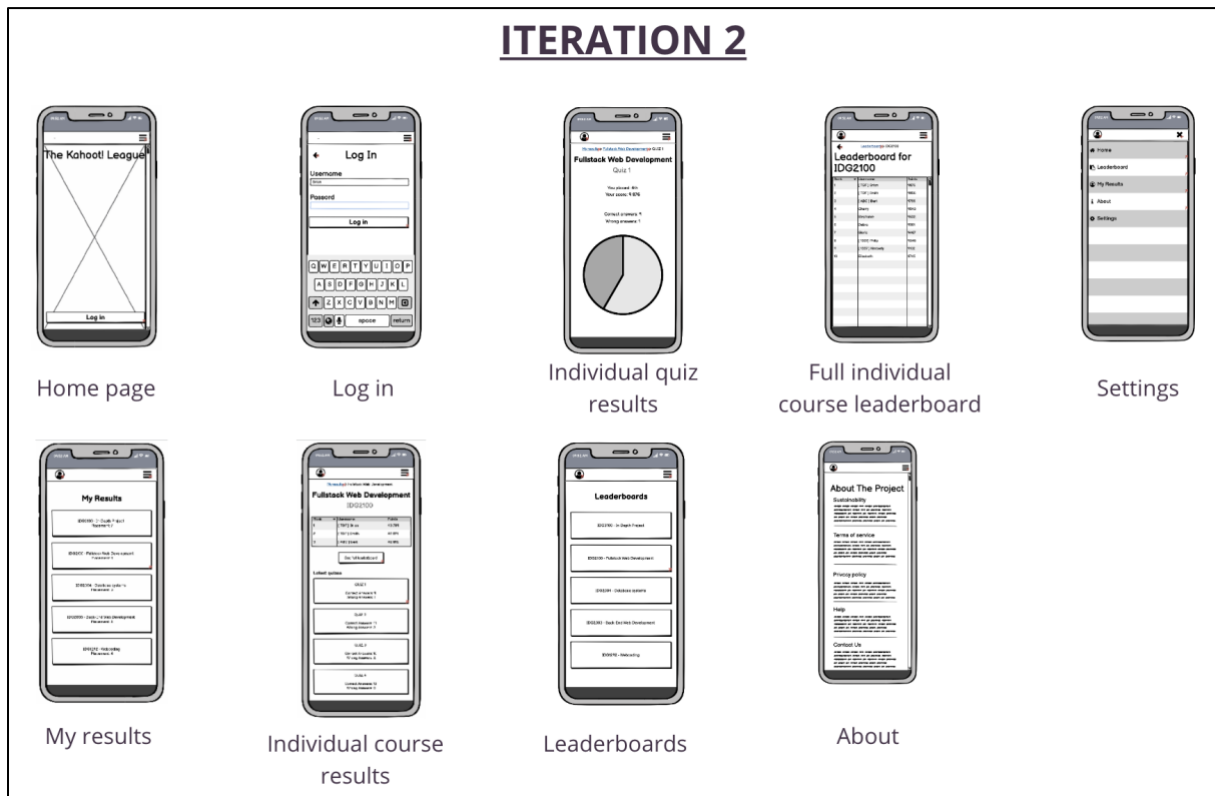


Figure 29. The second iteration of the low-fidelity design was created in Balsamiq.

The second iteration, Figure 29, has been changed with improvements from feedback given during the usability test (see the following section). For instance, the information architecture was changed on the “Individual quiz results”-page. Then on the “Individual course results”-page, the line graph was replaced by a snippet of the leaderboard. Lastly, the items on the “Leaderboards”-page was converted to a full-screen list, making it easier to select items.

## 4.2.5 Results from usability testing

In this section, we will begin by examining the usability test results. We will then examine the system's usability scores for each usability test.

### 4.2.5.1 Usability tests

Our initial design incorporated uploading and management functionality solely within the manage panel. However, during our usability test on these users, all respondents went into a course to upload a quiz instead. As a result, we discovered that all admins have a different mental model than us.

Our mental model was as follows: Start on the home screen, navigate to the manage page, and click the upload quiz button. However, the respondent's mental model was: Start on the home screen, navigate to the leaderboard, click on a specific course, and expect an upload button to

be visible. Figure 31 below is a visualization of the different mental models.

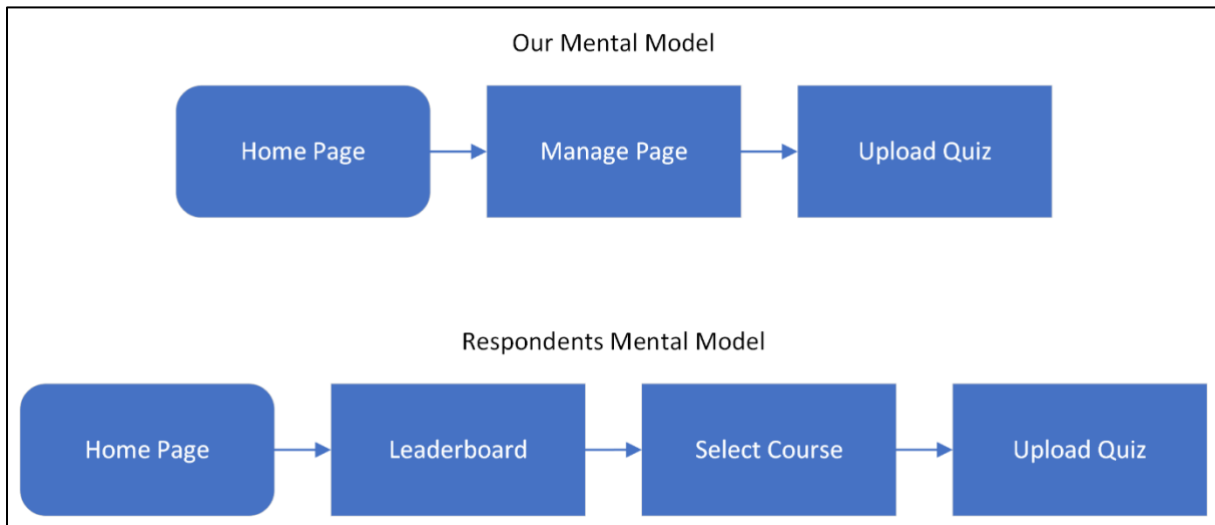


Figure 30. Diagram displaying the different mental models found during usability testing

The results of the initial usability test conducted with students are included in *Appendix 13: Results from usability test #1 with students*. The most common mistake that was found was navigation. Students struggled to navigate the prototype. For the five participants that participated in the usability test, there were four errors (See Figure 31). Changes were made before the second usability test targeted at students, see 3.1.4 *Creating low-fidelity prototypes*. There were six participants and two errors (See Figure 32 and *Appendix 14: Results from usability test #2 for students*). The error the participants made was navigation; however, adding label text under the navigation icons would help resolve this issue.

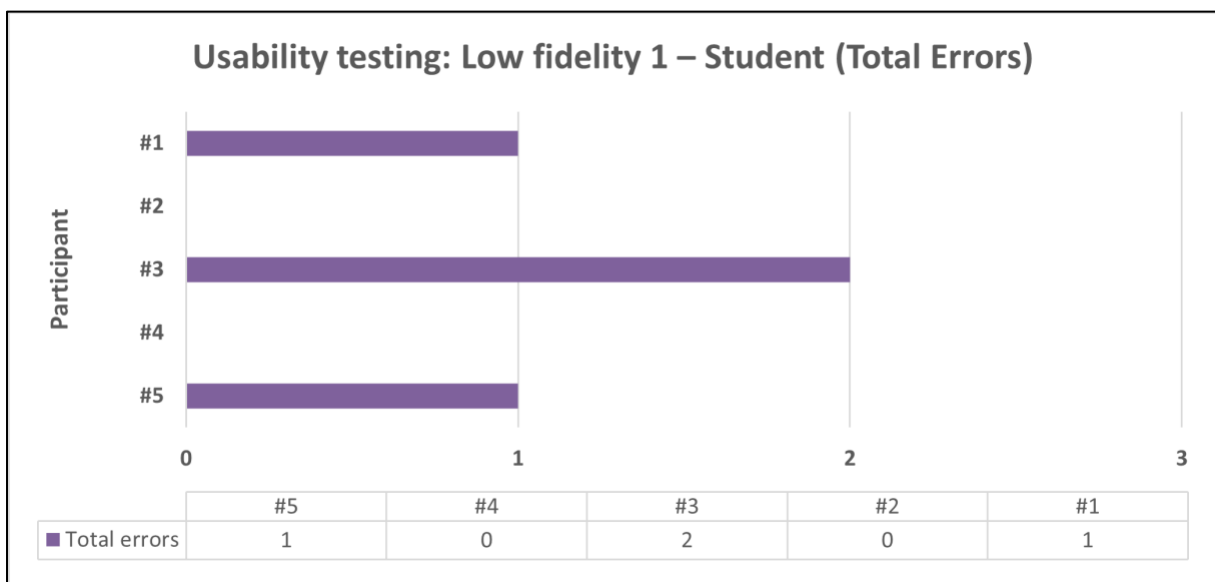


Figure 31. Usability testing: Low fidelity 1 – Student (Total Errors)

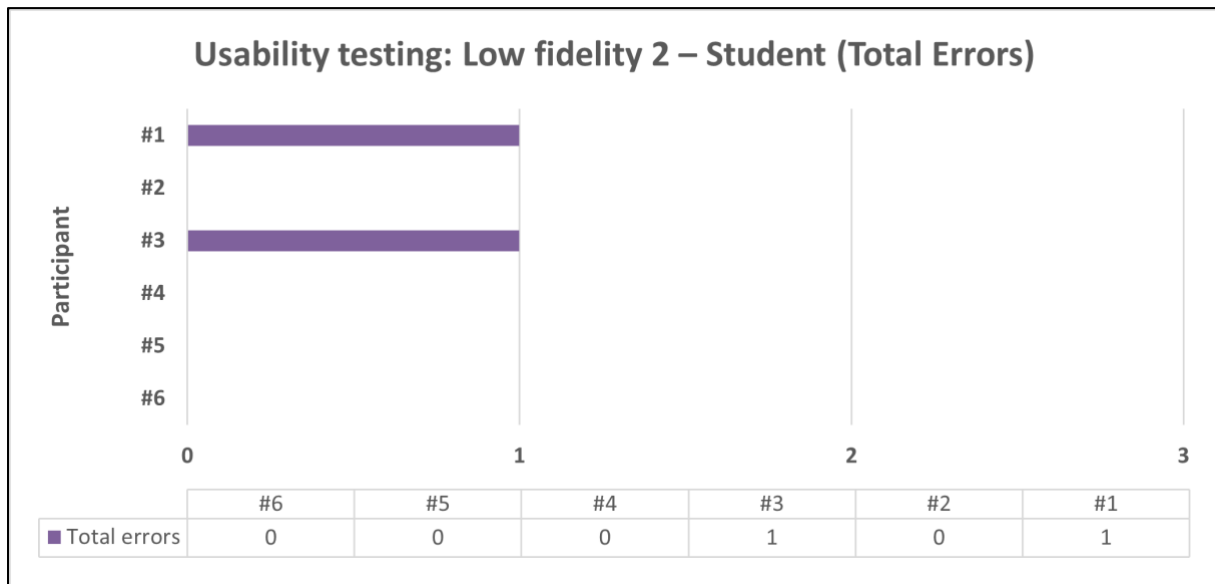


Figure 32. Usability testing: Low fidelity 2 – Student (Total Errors)

We have now included the results of the usability tests conducted on students. As can be seen, the students performed well on the first and second design iterations, as many interactions went according to plan. We will now consider the administrator usability tests.

The findings of the initial usability test conducted with administrators are included in *Appendix 15: Results from usability testing #1 for administrators*. There were a total of five participants and a total of 28 errors (See Figure 33). These were navigation and, as mentioned above, the mental model (Figure 32). Changes were made before the second usability test for administrators (see *Appendix 16: Results from usability testing #2 for administrators*. There were four participants, with a total of 5 errors (See Figure 34). These were problems with navigating, which would be fixed by adding label text to navigation icons. The administrators ran into problems with the initial design. Administrators could use the uniLeague more effectively after iterating our design in response to feedback.

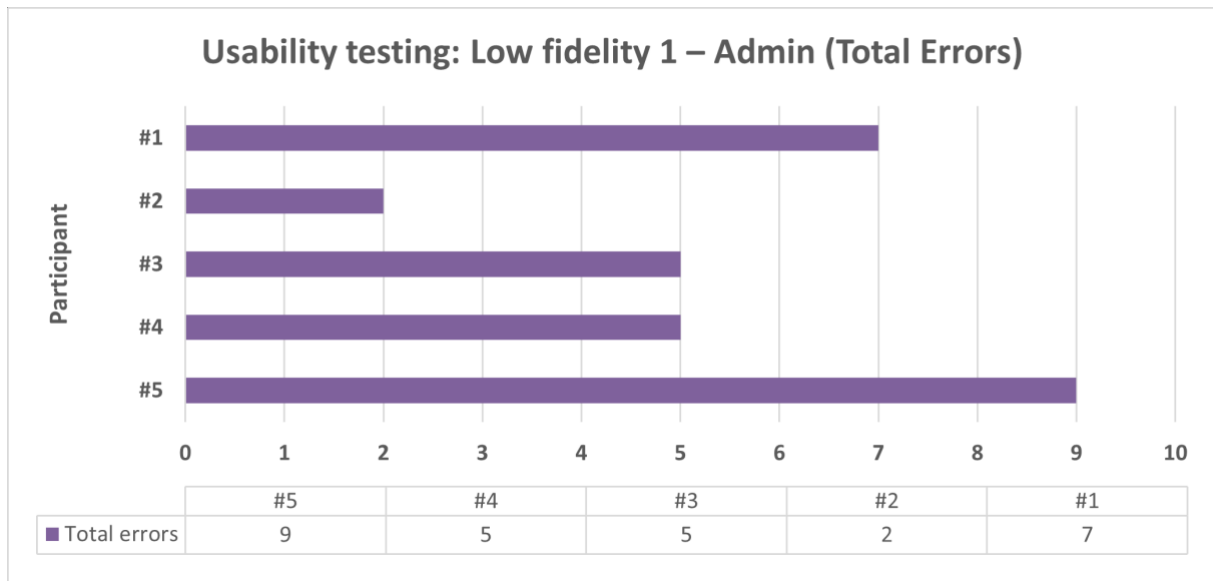


Figure 33. Usability testing: Low fidelity 1 – Admin (Total Errors)

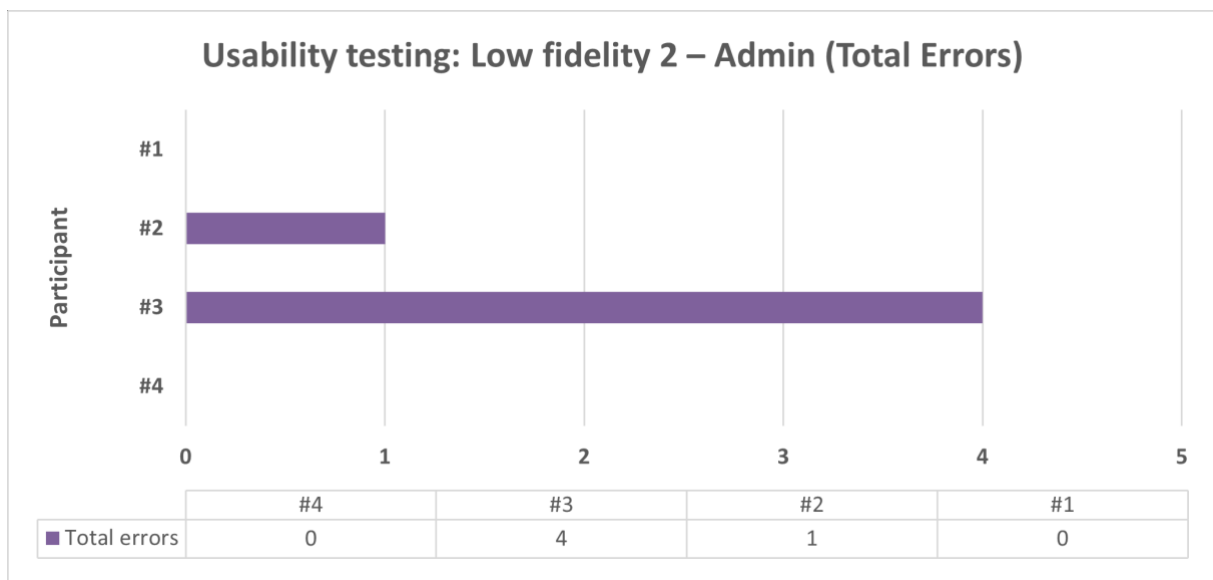


Figure 34. Usability testing: Low fidelity 2 – Admin (Total Errors)

As seen in appendices mentioned above, the time to complete each task varies drastically. Additionally, because each participant was asked to think aloud, considerable time was spent explaining their thinking, which varied significantly between participants. As a result, we have chosen not to quantify improvement or deterioration in terms of time in this study.

We have presented the usability tests; the following section will discuss the SUS associated with each test.

#### 4.2.5.2 System usability score

To calculate the total SUS score used in this section, refer to chapter 3.1.5.9 *Calculating the SUS score* above.

The results of the system usability score are presented in the same order as the usability tests above. The first section is the results of the questionnaires the students took. The second section includes the results from the questionnaires the administrators took. Before examining the results, it is essential to note that while the system usability score questionnaire contains the same questions, the respondents in the two sections had completed different tasks before taking the questionnaire.

We are now turning to the results from the student-related tasks.

For the first usability test, there was a total of five participants. Of these five, only three responded to the system usability scale questionnaire. The results from this questionnaire can be found in the figures below.

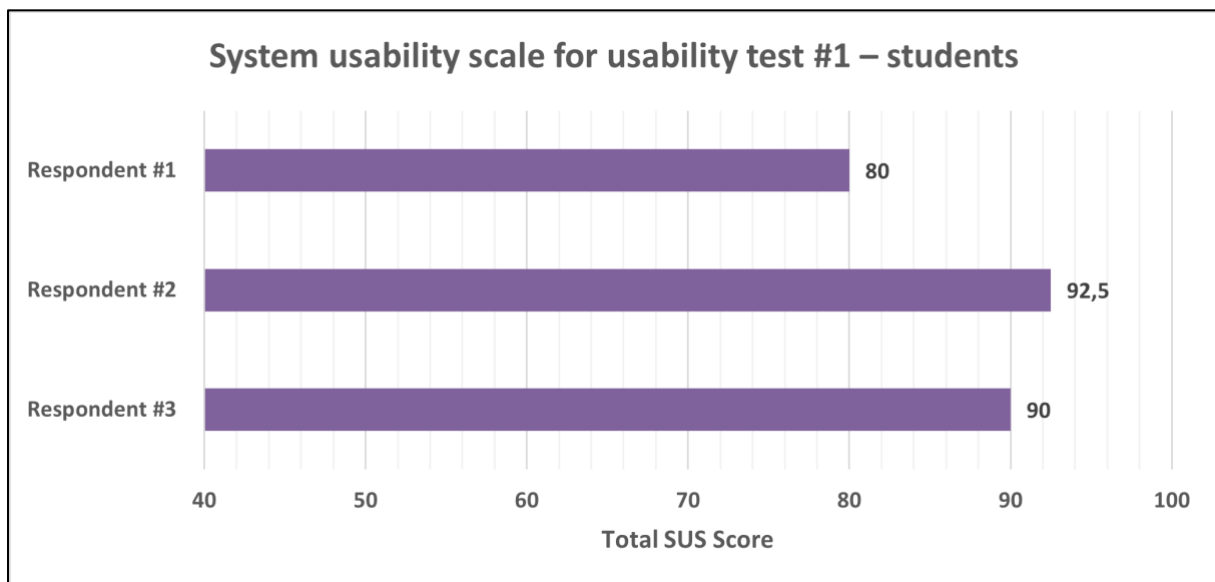


Figure 35. System usability scale for usability test #1 for students

With 95% confidence, the population mean is between 80 and 95, based on only three samples. The average SUS score for the first iteration aimed at students is 83.3.

Below are the results of the second system usability scale questionnaire targeted toward students.

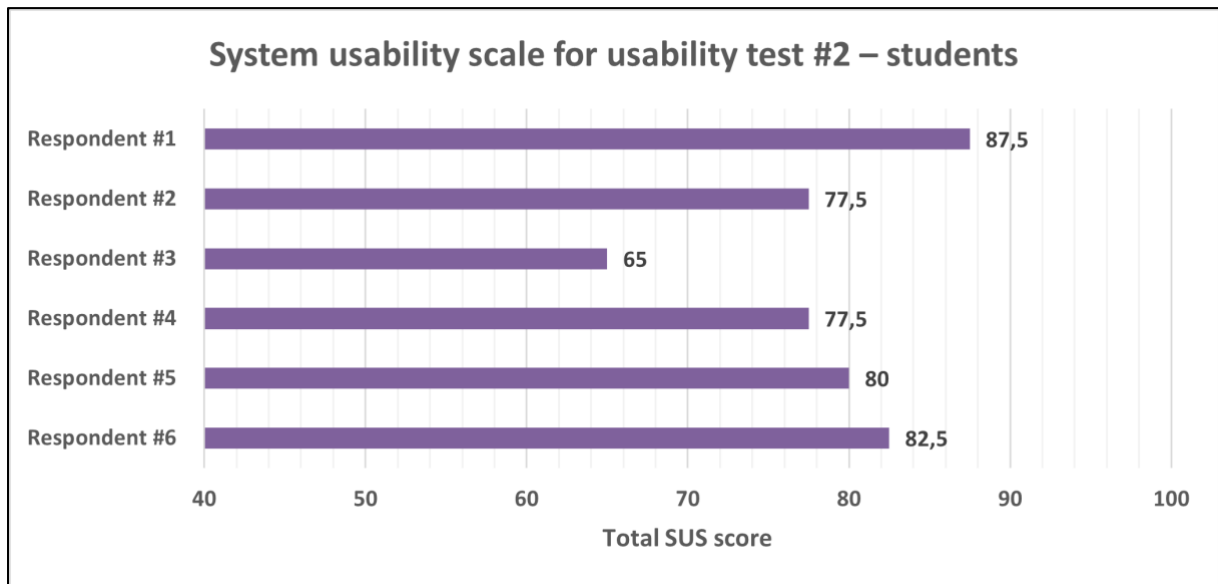


Figure 36. System usability scale for usability test #2 for students

With 95% confidence, the population mean is between 72.3 and 84.3, based on only six samples. The average SUS score for the second iteration aimed at students is 78.3 (A decrease of 5 points from the first iteration. We will discuss this further in section 5.1.1.1 *Usability Test*.

We have now seen the results of the two SUS questionnaires completed by the students. We are now going to move on to the SUS questionnaire for administrators.

The following figure summarizes the results of the first system usability score questionnaire for administrators.

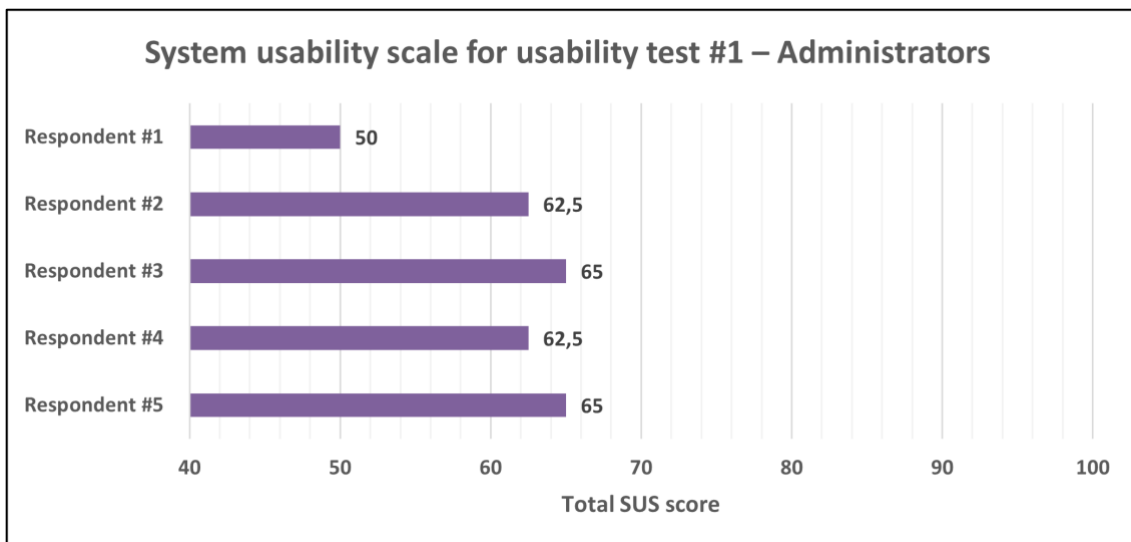


Figure 37. System usability scale for usability test #1 for administrators

With 95% confidence, the population mean is between 55.5 and 66.5, based on only five samples. The average SUS score for the first iteration aimed at administrators is 61.

The second system usability score questionnaire for administrators is listed below.

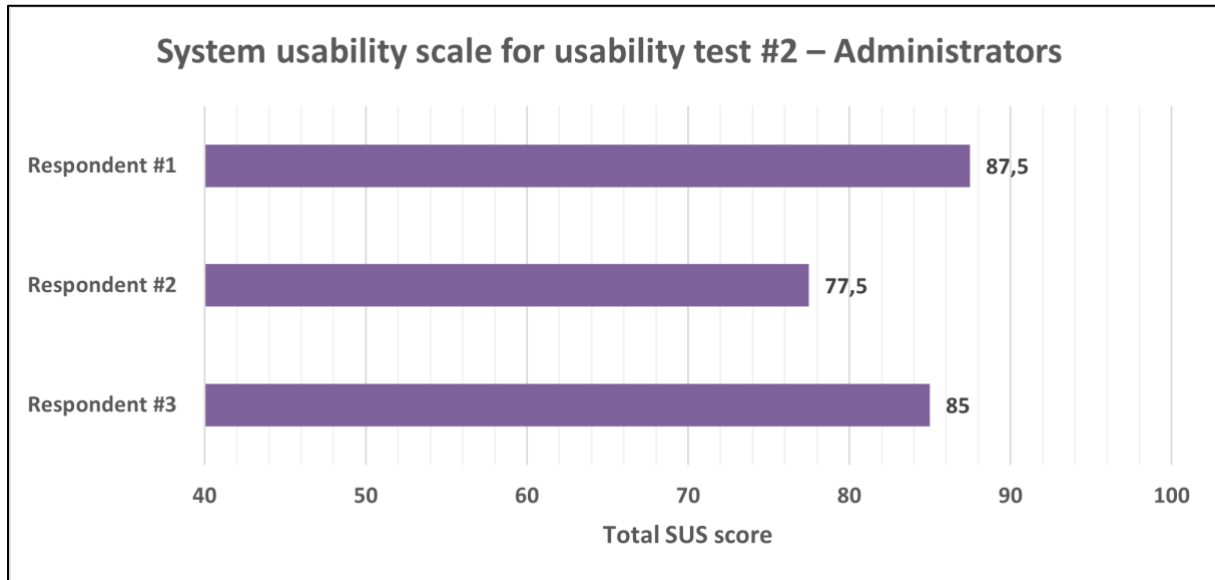


Figure 38. System usability scale for usability test #2 for administrators

With 95% confidence, the population mean is between 77.4 and 89.2, based on only three samples. The average SUS score for the second iteration aimed at administrators is 83.3 (An increase of 20.3 points from the first iteration).

The biggest takeaway is that the respondents' mental model differed from what we initially thought. A mismatch between mental models meant that the first iteration had many errors, especially with administrators. We also noticed that it required many clicks to view specific results. The solution was to change the mental model and bring information forward to be presented with the "important" information as soon as possible.

For students, the average SUS score for the first design iteration was 83.3, while the average SUS score for administrators was 61. These scores put the first iteration in the " Okay " – "Good" category (See section 2.3.6.1 *System Usability Score*), and the design should be improved.

For the second iteration, we noticed that most of the issues from the first iteration were fixed. The most momentous change from the first iteration to the second was that the burger menu was replaced by a bottom navbar with label text. The label text was given better naming so the user could understand what it was supposed to represent. All "important" information was brought to the forefront, reducing the time required to complete specific tasks.

For students, the average SUS score was 78.3 for the second iteration, while for administrators, the SUS score was 83.3. These scores put the second iteration in the “Good” – “Excellent” category and are considered good enough (See section 2.3.6.1 *System Usability Score*).

This section has presented the results from the usability testing and their SUS score. The following section moves on to consider the results from the development phase.

#### 4.2.6 High-fidelity prototype results

The result of high-fidelity prototyping is used as a guide for development (see section 2.3.7 *High-fidelity prototyping*) and is highly similar to the final product. Section 3.1.6 *Creating the high-fidelity prototype* mentioned that it was designed for mobile and desktop devices, and it was also intended for three different views of the roles mentioned in section 2.1.1 *Defining target audiences*. We will, therefore, display screenshots from the high-fidelity design in the same order.



Figure 39. The high-fidelity prototype of the mobile view of uniLeague



Figure 39 shows the design for mobile. The small window means we have to show the most crucial details first.

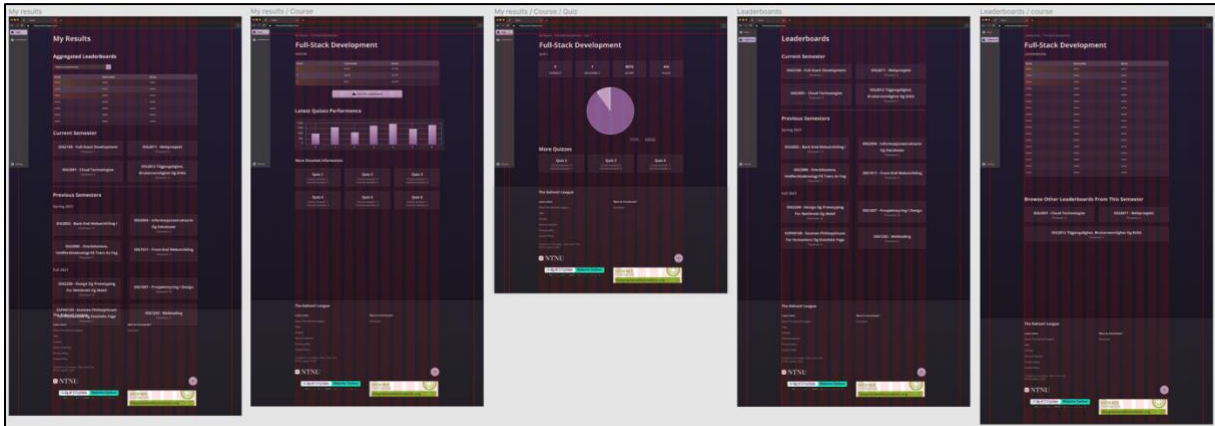


Figure 40. The High-fidelity prototype of the desktop view of uniLeague.

Figure 40 shows the design for the desktop version. As the initial design was for mobile, the desktop is a larger version as it has more real estate than mobile.

## 4.3 Results from development

This section will look at the second part of the first problem area, *design and develop a web application*. For the direct results from the front-end and back-end development, see section 4.1 uniLeague – Web Application above.

### 4.3.1 Database structure

Section 3.2.2 *Setting up the back-end* results are a database consisting of five collections. Figure Figure 41 shows the "studyprogrammes" collection with a study program that has six study periods (bachelor), has one course in study period number four, which is the second year, second semester, and has 28 users.

```

FILTER { field: 'value' }

{
  "_id": ObjectId("62374e8ad8bc3cd1b048a85b"),
  "name": "Bachelor In Web Development",
  "programmeCode": "BWU",
  "year": 2020,
  "startTerm": "fall",
  "studyPeriods": Array
  > 0: Object
  > 1: Object
  > 2: Object
  > 3: Object
    "periodNumber": 4
    "dates": Object
      "term": "spring"
      "startDate": "Januar"
      "endDate": "Juni"
      "code": "BWU2-20"
      "name": "Bachelor In Web Development-2.year"
      "startTerm": "fall"
    "courses": Array
      0: ObjectId("623754e8ad8bc3cd1b048a85f")
  > 4: Object
  > 5: Object
  "users": Array
    0: ObjectId("6237546b8acb2fe9e8ea6c45")
    1: ObjectId("623754808acb2fe9e8ea6c49")
    2: ObjectId("623754988acb2fe9e8ea6c4d")
    3: ObjectId("623754b08acb2fe9e8ea6c51")
    4: ObjectId("623754c68acb2fe9e8ea6c55")
    5: ObjectId("623754d38acb2fe9e8ea6c59")
    6: ObjectId("623754ea8acb2fe9e8ea6c5d")
    7: ObjectId("6237550b8acb2fe9e8ea6c61")
    8: ObjectId("6237551a8acb2fe9e8ea6c65")
    9: ObjectId("623755298acb2fe9e8ea6c69")
    10: ObjectId("623755408acb2fe9e8ea6c6d")
    11: ObjectId("623755528acb2fe9e8ea6c71")
    12: ObjectId("6237555f8acb2fe9e8ea6c75")
    13: ObjectId("623755718acb2fe9e8ea6c79")
    14: ObjectId("623755828acb2fe9e8ea6c7d")
    15: ObjectId("6237559e8acb2fe9e8ea6c81")
    16: ObjectId("623755b18acb2fe9e8ea6c85")
    17: ObjectId("623755c08acb2fe9e8ea6c89")
    18: ObjectId("623755d08acb2fe9e8ea6c8d")
    19: ObjectId("623755df8acb2fe9e8ea6c91")
    20: ObjectId("6237556288acb2fe9e8ea6c99")
    21: ObjectId("623756378acb2fe9e8ea6c9d")
    22: ObjectId("623756478acb2fe9e8ea6ca1")
    23: ObjectId("623756548acb2fe9e8ea6ca5")
    24: ObjectId("6237566a8acb2fe9e8ea6ca9")
    25: ObjectId("6237521802aec12b8252b6ba")
    26: ObjectId("62374e2dbd075e5ed84370f4")
    27: ObjectId("6238b8976e09080776f1dc39")
  "studyProgrammeCode": "BWU20"
  "createdAt": 2022-03-20T15:55:54.141+00:00
  "updatedAt": 2022-03-21T17:41:00.274+00:00
}

```

Figure 41. Studyprogramme collection from MongoDB Atlas

### 4.3.2 Deployed web application

As mentioned in section 3.2.4 *Deploying the web application*, four guides were used to set up a Droplet: create a new admin user, install, and set up a webserver using NGINX, configure

Certbot to obtain certificates from Cloudflare, and serve the front-end and back-end using PM2. The four guides are divided into the following four subheadings:

1. Initial server setup
2. Configuring the webserver
3. Securing the website using SSL
4. Serving front-end and back-end on a single droplet

#### 4.3.2.1 Initial server setup

The DigitalOcean dashboard is used to create a Droplet with the following options: Ubuntu 20.04, basic plan, AMS3 for the data center region, and SSH keys for authentication see Figure 42.

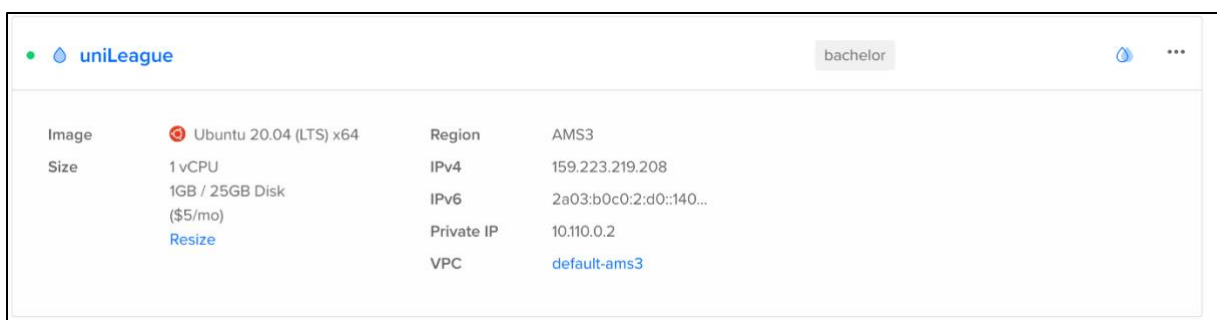


Figure 42. Droplet on DigitalOcean

#### 4.3.2.2 Configuring the webserver

NGINX is installed and verified using the command "systemctl status nginx", see Figure 43. A server block called "unileague.games" is created and configured as a reverse proxy<sup>25</sup>, see Figure 44.

---

<sup>25</sup> <https://www.nginx.com/resources/glossary/reverse-proxy-server/>

```
uni@unileague:~$ systemctl status nginx
● nginx.service - A high performance web server and a reverse proxy server
   Loaded: loaded (/lib/systemd/system/nginx.service; enabled; vendor preset: enabled)
   Active: active (running) since Tue 2022-03-29 21:29:35 UTC; 1 months 10 days ago
     Docs: man:nginx(8)
  Main PID: 131012 (nginx)
    Tasks: 2 (limit: 1131)
   Memory: 6.6M
    CGroup: /system.slice/nginx.service
            └─131012 nginx: master process /usr/sbin/nginx -g daemon on; master_process on;
               └─131014 nginx: worker process
```

Figure 43. Verify that NGINX is up and running

```
uni@unileague:/etc/nginx/sites-available$ cat unileague.games
server {
    if ($host ~ ^[^\.]+\.unileague\.games$) {
        return 301 https://$host$request_uri;
    } # managed by Certbot

    if ($host = unileague.games) {
        return 301 https://$host$request_uri;
    } # managed by Certbot

    listen 80;
    listen [::]:80;
    server_name unileague.games www.unileague.games;
    return 302 https://$server_name$request_uri;
}

server {
    # SSL configuration

    listen 443 ssl http2;
    listen [::]:443 ssl http2;
    ssl_certificate /etc/letsencrypt/live/unileague.games/fullchain.pem; # managed by Certbot
    ssl_certificate_key /etc/letsencrypt/live/unileague.games/privkey.pem; # managed by Certbot

    root /var/www/unileague.games/html;
    index index.html index.htm index.nginx-debian.html;
    server_name unileague.games www.unileague.games;

    location / {
        proxy_pass http://localhost:3000;
        proxy_set_header X-Forwarded-For $proxy_add_x_forwarded_for;
        proxy_set_header Host $host;
        proxy_set_header X-NginX-Proxy true;
        proxy_http_version 1.1;
        proxy_set_header Upgrade $http_upgrade;
        proxy_set_header Connection "upgrade";
        proxy_max_temp_file_size 0;
        proxy_redirect off;
        proxy_read_timeout 240s;
    }

    location /api/ {
        proxy_pass http://localhost:5000;
    }
}
```

Figure 44. “uniLeague.games” server block.

#### 4.3.2.3 Securing the website using SSL

Certbot is used to obtain certificates from Cloudflare to secure the connection from end-users to Cloudflare and Cloudflare to the origin server. To enable SSL/TSL encryption, the option

"Full (strict)" is checked on the Cloudflare dashboard, see Figure 45. A *crontab*, a time-based job scheduler, is used to renew certificates twice daily, see Figure 46. To verify that the web server uses a Cloudflare certificate, see Figure 47.

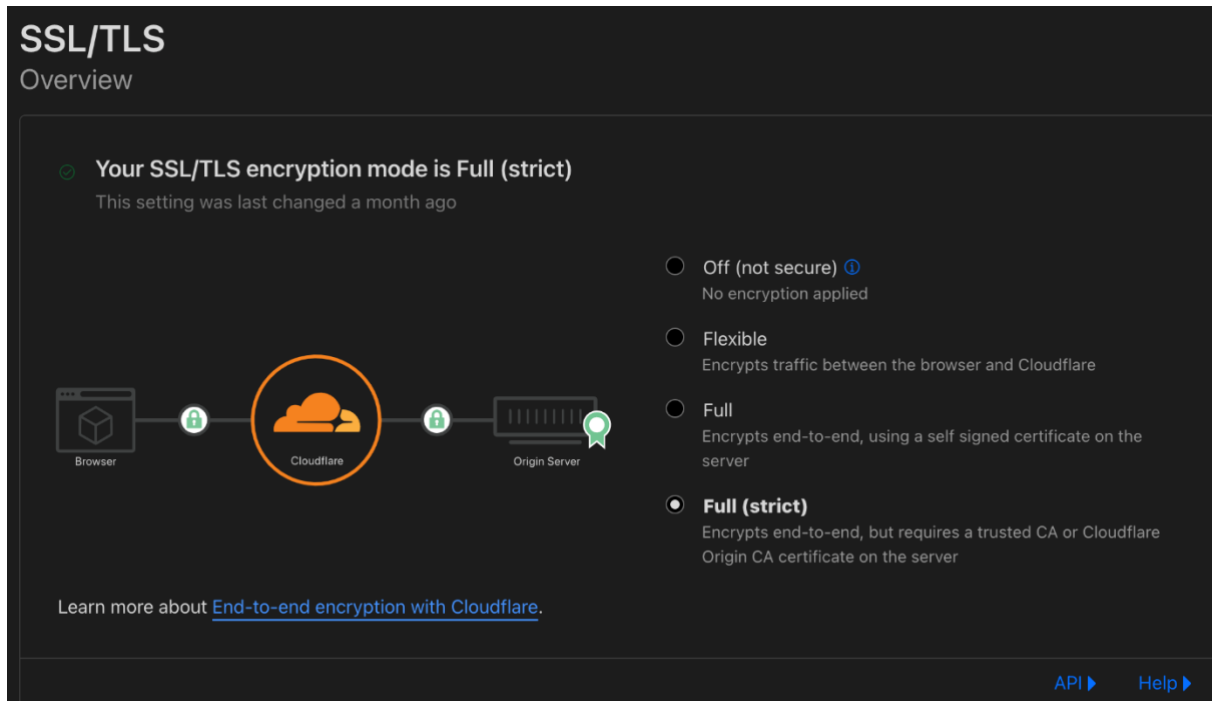


Figure 45. Cloudflare secure connection with HTTPS.

```
uni@unileague:~$ systemctl status certbot.timer
● certbot.timer - Run certbot twice daily
  Loaded: loaded (/lib/systemd/system/certbot.timer; enabled; vendor preset: enabled)
  Active: active (waiting) since Tue 2022-03-29 21:29:34 UTC; 1 months 10 days ago
  Trigger: Tue 2022-05-10 08:59:05 UTC; 14h left
  Triggers: ● certbot.service
```

Figure 46. Crontab timer for Certbot renewal of the certificate.

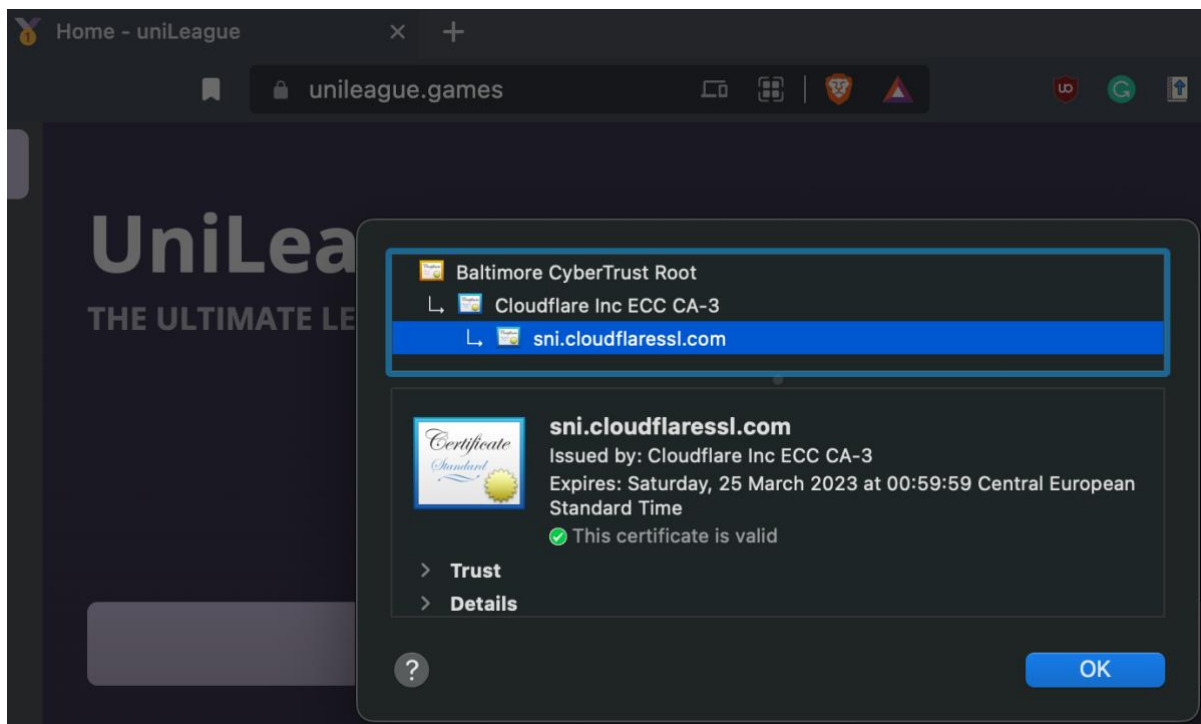


Figure 47. Valid Cloudflare certificate on "unileague.games".

#### 4.3.2.4 Serving front-end and back-end on a single Droplet

PM2 is used to start the front-end and back-end application processes separately and uses load-balance queries to increase the overall performance. To run the front-end application on the Droplet, a front-end build was moved to the path "/var/www/unileague.games/html/" on the server. The following command was used to start the front-end application: "pm2 start serve -- -s /var/www/unileague.games/html/", Figure 48 shows the application running. To run the back-end application on the Droplet, a clone of the back-end repository is cloned to the Droplet, and the following command was used to start the back-end application: "pm2 start index.js" see Figure 49.

See Figure 50 for both applications running simultaneously on the server.

```
uni@unileague:~$ pm2 show serve
Describing process with id 1 - name serve
```

status	online
name	serve
namespace	default
version	N/A
restarts	0
uptime	40D
script path	/usr/bin/serve
script args	-s /var/www/unileague.games/html/
error log path	/home/uni/.pm2/logs/serve-error.log
out log path	/home/uni/.pm2/logs/serve-out.log
pid path	/home/uni/.pm2/pids/serve-1.pid
interpreter	node
interpreter args	N/A
script id	1
exec cwd	/etc/nginx
exec mode	fork_mode
node.js version	17.8.0
node env	N/A
watch & reload	x
unstable restarts	0
created at	2022-03-29T21:23:02.204Z

```

Actions available
km:heapdump
km:cpu:profiling:start
km:cpu:profiling:stop
km:heap:sampling:start
km:heap:sampling:stop

Trigger via: pm2 trigger serve <action_name>

Code metrics value
Used Heap Size      16.15 MiB
Heap Usage          71.87 %
Heap Size           22.47 MiB
Event Loop Latency p95 1.18 ms
Event Loop Latency  0.39 ms
Active handles      4
Active requests     0
HTTP                0 req/min
HTTP P95 Latency    14.549999999999955 ms
HTTP Mean Latency   2 ms

```

Figure 48. Front-end process running on the server.

```
uni@unileague:~$ pm2 show index
Describing process with id 0 - name index
```

status	online
name	index
namespace	default
version	1.0.0
restarts	0
uptime	40D
script path	/home/uni/backend/index.js
script args	N/A
error log path	/home/uni/.pm2/logs/index-error.log
out log path	/home/uni/.pm2/logs/index-out.log
pid path	/home/uni/.pm2/pids/index-0.pid
interpreter	node
interpreter args	N/A
script id	0
exec cwd	/home/uni/backend
exec mode	fork_mode
node.js version	17.8.0
node env	N/A
watch & reload	x
unstable restarts	0
created at	2022-03-29T20:33:09.061Z

```
Revision control metadata
```

revision control	git
remote url	https://github.com/Bachelorproject-Spring-22/backend.git
repository root	/home/uni/backend
last update	2022-03-29T21:30:55.268Z
revision	c9142b10ad486e8278ebbc039c9089b065cf6b79
comment	Add 'short' instead of 'dev' on morgan
branch	production-v2

```
Actions available
```

```
km:heapdump
km:cpu:profiling:start
km:cpu:profiling:stop
km:heap:sampling:start
km:heap:sampling:stop
```

```
Trigger via: pm2 trigger index <action_name>
```

```
Code metrics value
```

Used Heap Size	39.00 MiB
Heap Usage	84.9 %
Heap Size	45.93 MiB
Event Loop Latency p95	1.22 ms
Event Loop Latency	0.40 ms
Active handles	10
Active requests	0
HTTP	0 req/min
HTTP P95 Latency	215.5 ms
HTTP Mean Latency	68 ms

Figure 49. Back-end process running on the server.

```
uni@unileague:~$ pm2 list
```

id	name	mode	⌘	status	cpu	memory
0	● index	fork	0	online	0%	84.4mb
1	serve	fork	0	online	0%	49.0mb

Figure 50. PM2 shows that the front-end and back-end are running.



## 4.4 Results from student course engagement questionnaire

This section will look at the results from the second problem area, *measure the engagement*. It will show the results from the Student Course Engagement Questionnaire (SCEQ).

The results from both the pre-and post-questionnaire can be found below (Figure 51 & Figure 52). Before we proceed, it is essential to know that there are limitations to smaller sample studies like ours ( $n < 30$ ). We are limited to seeing big differences or significant "effects" (if they exist). As sample size decreases, the ability of a study to detect slight or even moderate effects vanishes (Morgan, 2017; Sauro, 2013).

Each statement from the SCEQ corresponds to a stacked bar in the bar charts below. The charts are created by following Bounthavong's tutorial on visualizing Likert Scale data in Excel (Bounthavong, 2019). The charts are also strongly inspired by Heiberger and Robbins's *Design of Diverging Stacked Bar Charts for Likert Scales and Other Applications* (Heiberger and Robbins, 2014).

The color scheme uses red to indicate disagreement and blue to indicate agreement for the pre-questionnaire. For the post-questionnaire, orange is used to indicate disagreement and green to indicate agreement. Darker colors denote a greater degree of agreement. Gray denotes the "indifferent" position as it applies the same for both questionnaires. The neutral position bar is divided into half to the left and half to the right of the vertical zero reference line.

### 4.4.1 Pre-questionnaire results

The results from the pre-questionnaire are presented in Figure 51 below ( $n=13$ ).

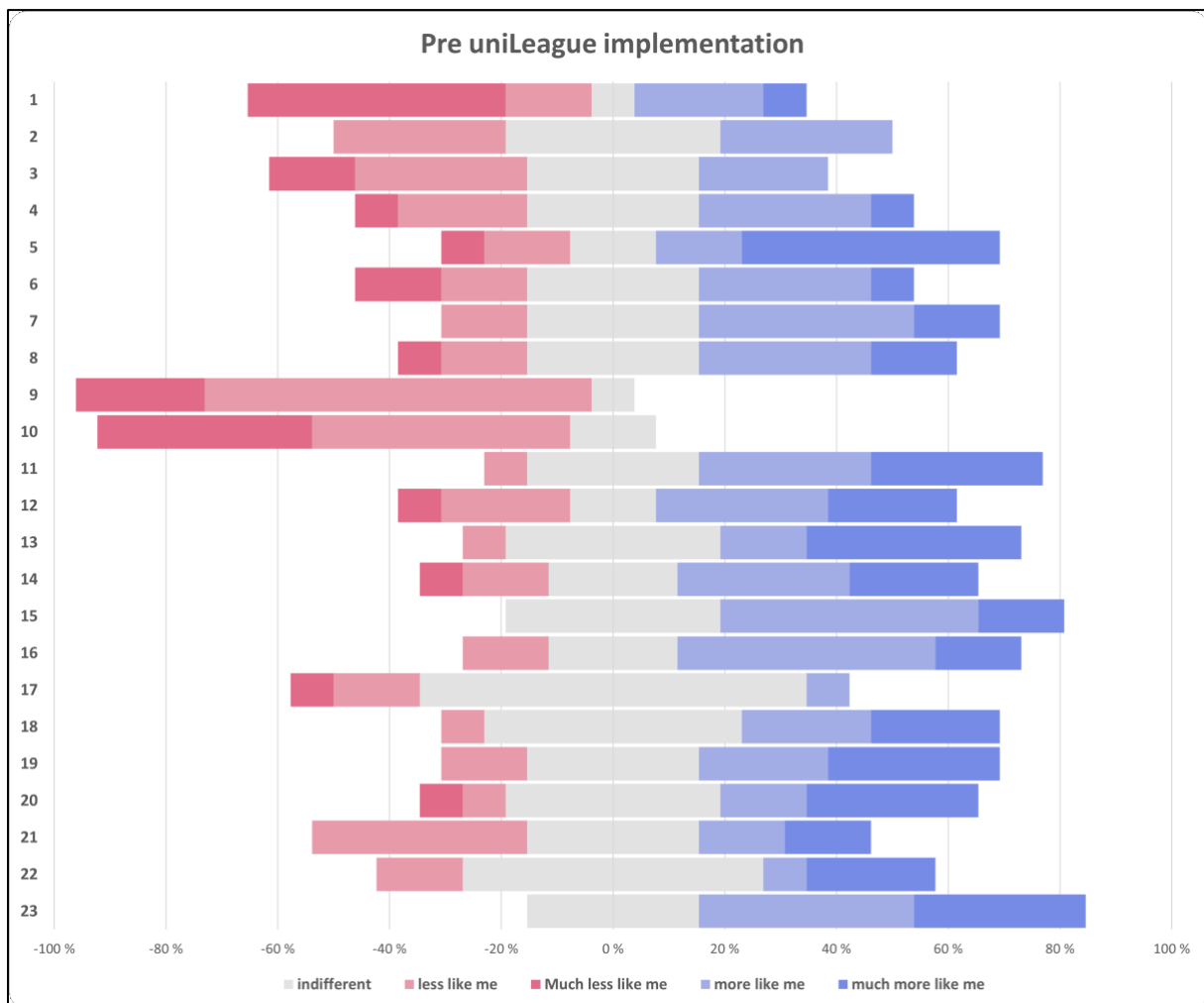


Figure 51. Chart displaying responses from the post-questionnaire (n=13).

Our data suggest that students agree with most of the statements with a few exceptions, such as items #1, #3, #9, and #10.

The questionnaire also consists of four categories, as mentioned in section 3.3.5 *Questionnaire design*. The individual categories will not be visualized here as minimal changes. However, we will describe the general agreement or disagreement for the categories.

#### 4.4.1.1 Skills engagement before uniLeague

For the pre-questionnaire, our data suggest that the students mostly agree with the *Skills engagement* statements, except for items #9 and #10, on which they strongly disagree. The category consists of items #4, #5, #9, #10, #13, #14, #17, #20, #13.

#### 4.4.1.2 Emotional engagement before uniLeague

For the pre-questionnaire, our data suggest that the students agree with the *Emotional engagement* category statements. The category consists of items #7, #8, #11, #21 and #22.

4.4.1.3 Participation/interaction engagement before uniLeague

Our data suggest that the students agree with most *Participation/interaction engagement* statements for the pre-questionnaire. The students seem to strongly disagree with two statements, namely #1 and #3. The category consists of items #1, #2, #3, #6, #18, #19

4.4.1.4 Performance engagement before uniLeague

For the pre-questionnaire, the students seem to strongly agree with the statements, especially item #15 in the *Performance engagement* category. The category consists of items #12, #15, and #16.

4.4.2 Post-questionnaire results

The next part of this section will present the results from the post-questionnaire in Figure 52 below ( $n=12$ ).

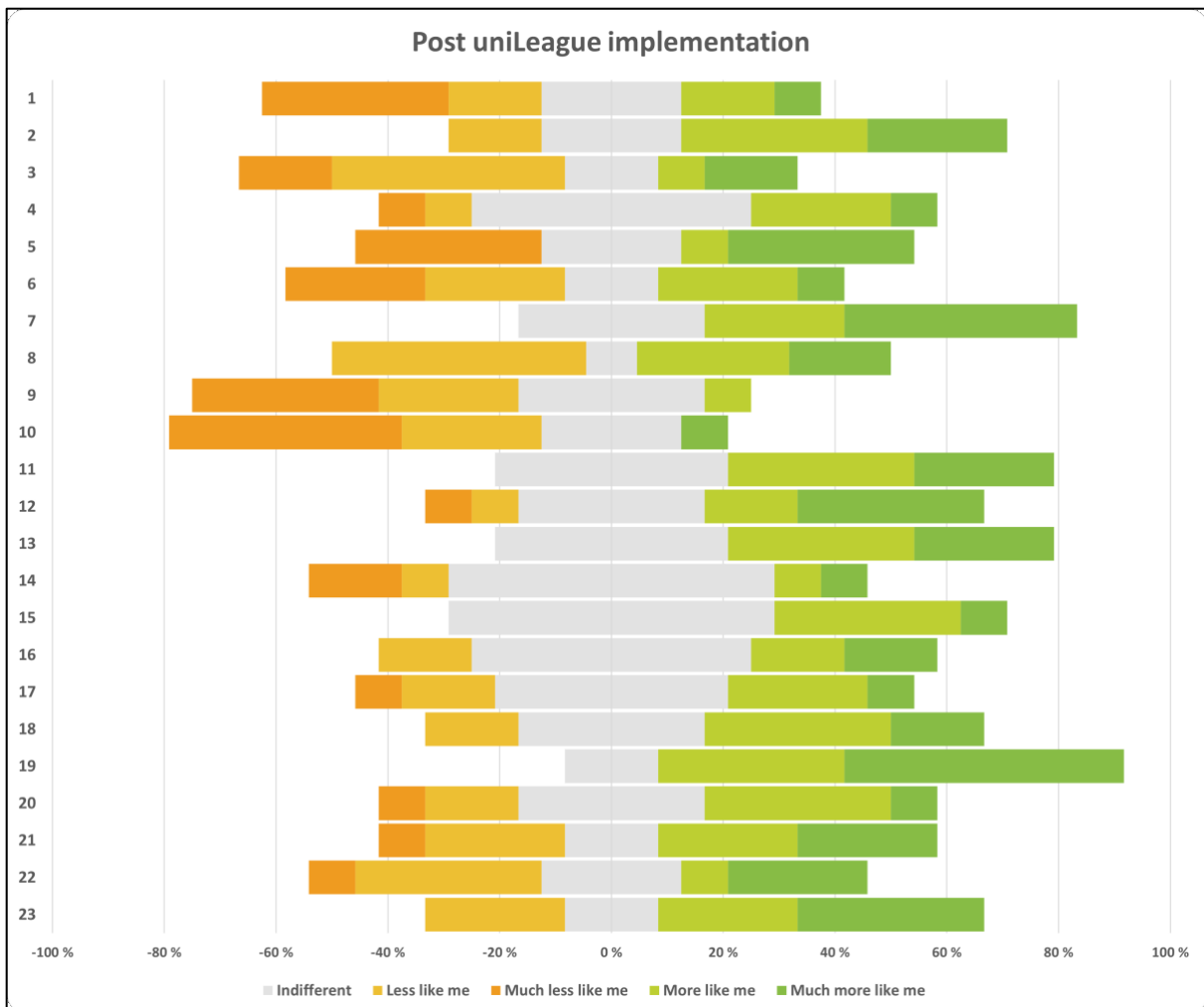


Figure 52. Chart displaying responses from the post-questionnaire ( $n=12$ )

#### 4.4.2.1 *Skills engagement after uniLeague*

Our data suggest that the student students strongly disagree with statements #9 and #10 in the *Skills engagement* category but strongly agree with statement #13. The students appear to be indifferent to the remaining items in the category (#4, #5, #14, #17, #20, #23)

#### 4.4.2.2 *Emotional engagement after uniLeague*

Our data suggest students strongly agree with statements #7 and #11 in the *Emotional engagement* category. The students seem indifferent to the other statements (#8, #21, and #22).

#### 4.4.2.3 *Participation/interaction engagement after uniLeague*

Our data suggest that the students strongly agree with #19. In contrast, students disagree with statements #3 and #6. The other statements (#1, #2, and #18) have mixed responses in the *Participation/interaction engagement* category.

#### 4.4.2.4 *Performance engagement after uniLeague*

The students seem to agree with all statements (#12, #15, and #16) in the *Performance engagement* category after using uniLeague

### 4.4.3 Comparing pre and post questionnaire results

Figure 53 below shows the five items with the most significant changes between the questionnaires. The remaining statements have not changed significantly, so they will not be displayed.

On the left-hand side, each statement is numbered (see section 3.3.5 *Questionnaire design*). The upper bar (red and blue) displays the pre-questionnaire results, while the lower bar (orange and green) displays the post-questionnaire results.

The color scheme for the pre-questionnaire uses red to indicate disagreement and blue to indicate agreement. Orange indicates disagreement on the post-questionnaire, while green indicates agreement. Darker colors indicate a higher level of concurrence.

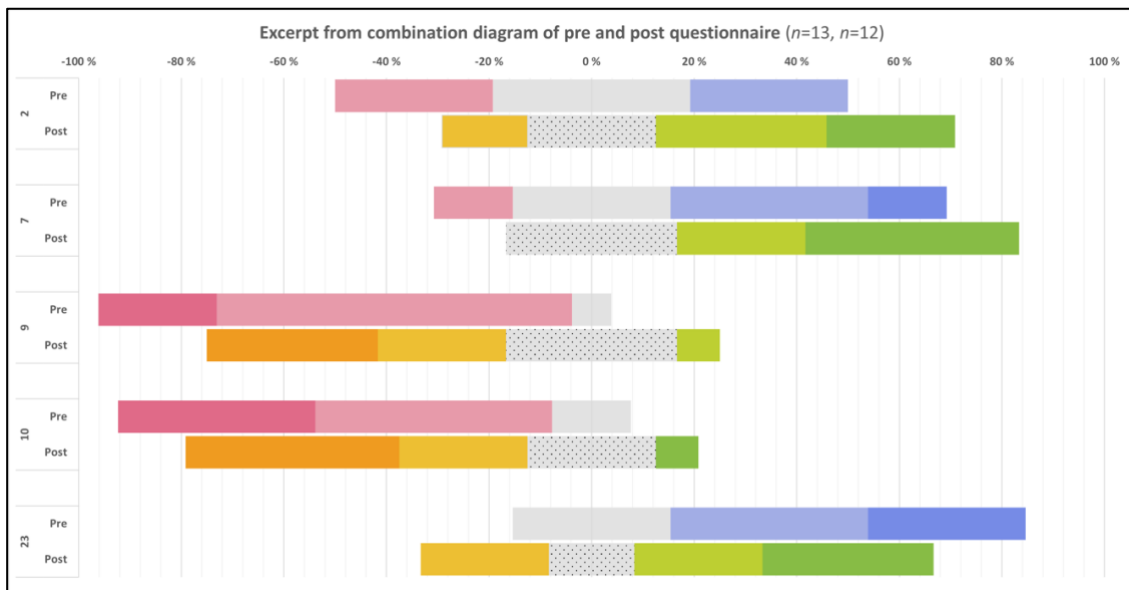


Figure 53. Chart displaying the most significant changes between the pre-and post-questionnaires.

Right-leaning bars indicate more engaged students. Left-leaning bars indicate less engaged students. Our data suggest that students became more engaged when it comes to statements (#2) *Participating actively in small group discussions*, (#7) *Thinking about the course between class meetings*, (#9) *taking good notes*, (#10) *looking over class notes between classes*. In contrast, our data suggest students became less engaged regarding (#23) *listening carefully in class*.

#### 4.4.3.1 Comparing skills engagement category

By loosely comparing the items from the skills engagement category, students seem to agree more with statements #9 and #10 after using uniLeague. In contrast, students seem to disagree more with statement #23.

#### 4.4.3.2 Comparing the emotional engagement category

Students seem to agree more with statements #7 and #11 after using uniLeague. In contrast, students disagree more with statement #22 than before.

#### 4.4.3.3 Comparing the participation/interaction engagement category

The students seem to agree more with statement #19 after using uniLeague. The other statements did not change significantly.

#### 4.4.3.4 Comparing the performance engagement category

Our data suggest minimal changes in the performance engagement category after using uniLeague.

To conclude this section, the questionnaire provided some insight into the student's engagement prior to and following the use of uniLeague in class. It is not easy to discern a

significant difference between the pre-and post-questionnaires. There appears to be a slight improvement toward increased engagement.

#### 4.4.4 Response rate analysis

Completed SCEQs were returned from 13 students – a response rate of 50% – for the pre-questionnaire, and 12 students returned a completed SCEQ for the post questionnaire, resulting in a response rate of <50%.

The section below further describes the representativeness, gender distribution, and response rate regarding the SCEQ. Each section covers both the pre-questionnaire and post-questionnaire.

##### 4.4.4.1 Calculating reliability

To determine how many participants our questionnaire needs, we turn to SurveyMonkey’s “sample size calculator.”<sup>26</sup> This tool helps us determine how many participants we need to take our questionnaires to make the data statistically significant. The tool requires three fields to be filled: *population size*, *confidence level*, and *margin of error*. In IDG2100, there are a total of 26 students. Our confidence level is 95%, which means that we believe that our sample will reflect the attitude of our users (this is also the industry standard).

Furthermore, we calculate our margin of error. To calculate the margin of error, we used SurveyMonkey’s “margin of error calculator,”<sup>27</sup> which needs three fields to be filled. These are *population size*, *confidence level*, and *sample size*.

We have a margin of error equal to 20% (21% for the second survey). As stated, there is a total of 26 students available to take the survey, our confidence level is 95%, and the number of people that took our pre-questionnaire was 13 (12 for the post-questionnaire). This gives us a margin of error equal to 20% for the first survey and 21% for the second survey.

If we input these numbers into the “sample size calculator” provided by SurveyMonkey, we get a sample size of 13 for both questionnaires.

---

<sup>26</sup> See <https://www.surveymonkey.com/mp/sample-size-calculator/> for sample size calculator.

<sup>27</sup> See <https://www.surveymonkey.com/mp/margin-of-error-calculator/> for margin of error calculator.

#### 4.4.5 Gender distribution representative

The gender distribution is 11 males and 2 females (85% male and 15% female) for the pre-questionnaire. Similarly, the gender distribution for the post-questionnaire is 9 male, 1 female, 1 "prefer not to say," and 1 "other" (75% male, 8% female, 8% "prefer not to say," and 8% "other").

#### 4.4.6 Individual question response rate

The response rate was 100% for all individual questions for the pre-questionnaire. On the post-questionnaire, one respondent did not answer: "Finding ways to make the course interesting to me."

The data from the pre questionnaire suggest students lean toward being more engaged than not. In contrast, the students strongly disagree with two statements, namely items #9 and #10.

After using uniLeague in class for three weeks and completing the post-questionnaire, our data indicate that students became slightly more motivated than before using uniLeague. For example, students agreed more to statements #2, #7, #9, #10, #11, and #19. Therefore, our results align with studies claiming that gamification increases student engagement, such as uniLeague. Refer to Aleksic-Maslac, Rasic, and Vranesic, 2018; Vaibhav and Gupta, 2014; Rojas-López et al., 2019. As for the categories, there seem to be minimal changes, and no category seems to be affected more noticeably than others.

Based on our pre-and post-questionnaire, we can conclude that uniLeague *slightly* increased the engagement in the class.

### 4.5 UN sustainability & Sustainable web design

Lastly, this section will look at the results from the third and final problem area, *ensure sustainability*.

#### 4.5.1 Using green hosting

The result is a web page estimated to be 90% cleaner than other web pages tested on [websitescarbon.com](http://websitescarbon.com). The website has a page weight (the total size of a webpage) of about 555 kB measured from the *My Results > individual course* page. Our page weight is 72.25% smaller than the average website (Greenwood, 2021, pp. 37).

uniLeague is hosted on Digital Ocean, which claims its data center runs on 100% renewable energy in a Twitter thread (DigitalOcean, 2020). It is difficult to confirm what DigitalOcean

says on Twitter. Third-party tools such as [websitecarbon.com](https://www.websitecarbon.com/)<sup>28</sup> and [ecograder.com](https://ecograder.com/)<sup>29</sup> have, therefore, been used. The following tool states that uniLeague is hosted green. Therefore, we conclude that the servers for DigitalOcean hosted on AMS3 are green. The following images: Figure 54 and Figure 56 are results from Website Carbon Calculator and Ecograder.

Website Carbon Calculator says calculating a website's carbon footprint is complicated, but they are working on a methodology. A web page's energy and carbon emissions are calculated in five steps as explained by Wholegrain Digital (2022):

1. Data transfers over the wire.
2. Energy intensity of the web data.
3. Energy source used by the data center.
4. Carbon intensity of electricity.
5. Website traffic.

Because each tool may employ a unique algorithm, results vary between tools.

---

<sup>28</sup> <https://www.websitecarbon.com/>

<sup>29</sup> <https://ecograder.com/>



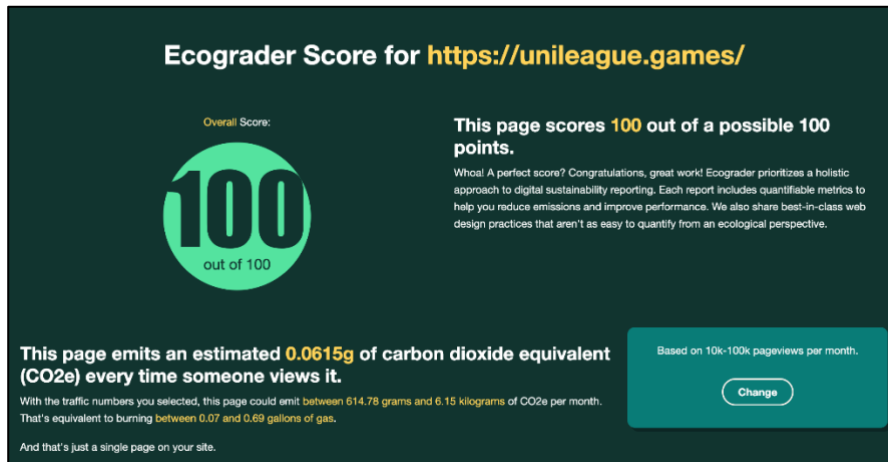


Figure 55. uniLeague's results from Ecograder

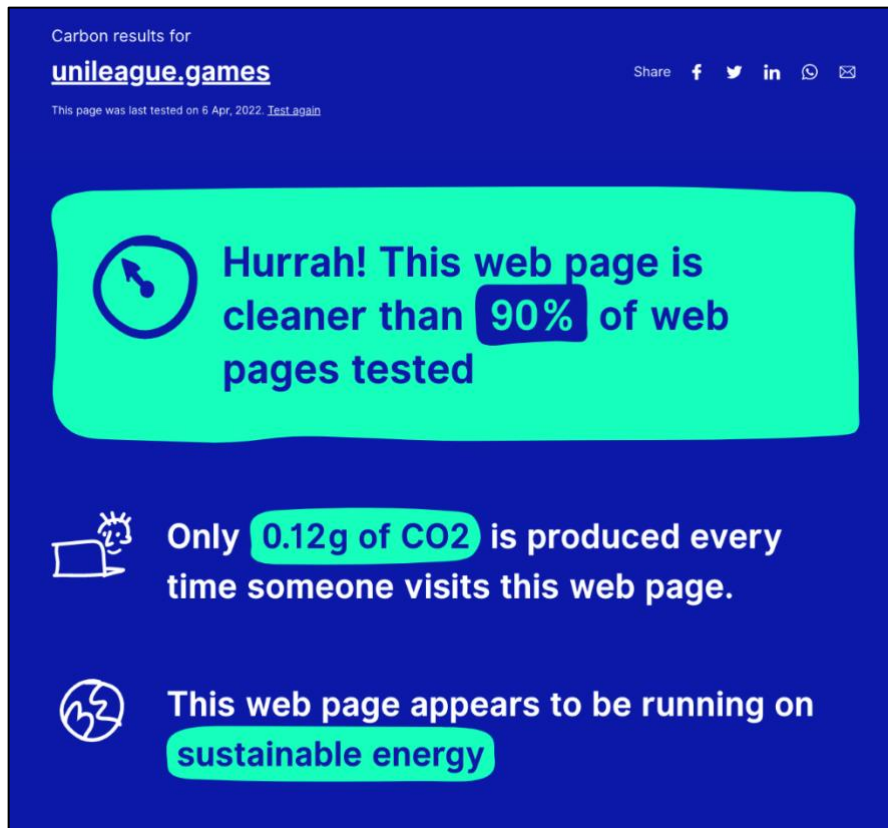


Figure 54. uniLeague's results from Website Carbon Calculator (version 3)

We want to note that these tools to measure sustainability must be taken with a massive grain of salt. See section 5.3.1 *Contributing to UN Sustainable Development Goal 13*.

### 4.5.2 Using Content Delivery Network

Cloudflare Analytics was used to determine the benefits of using a CDN for uniLeague. "Requests Through Cloudflare" and "Bandwidth" were the most relevant data points. These data points indicate the total number of cached requests and bandwidth utilized. Figure 56 displays the statistic regarding requests through Cloudflare provided by the Cloudflare dashboard. The data is collected for 30 days, 21.03–21.04. Additionally, Figure 57 displays the total saving measured in megabytes.

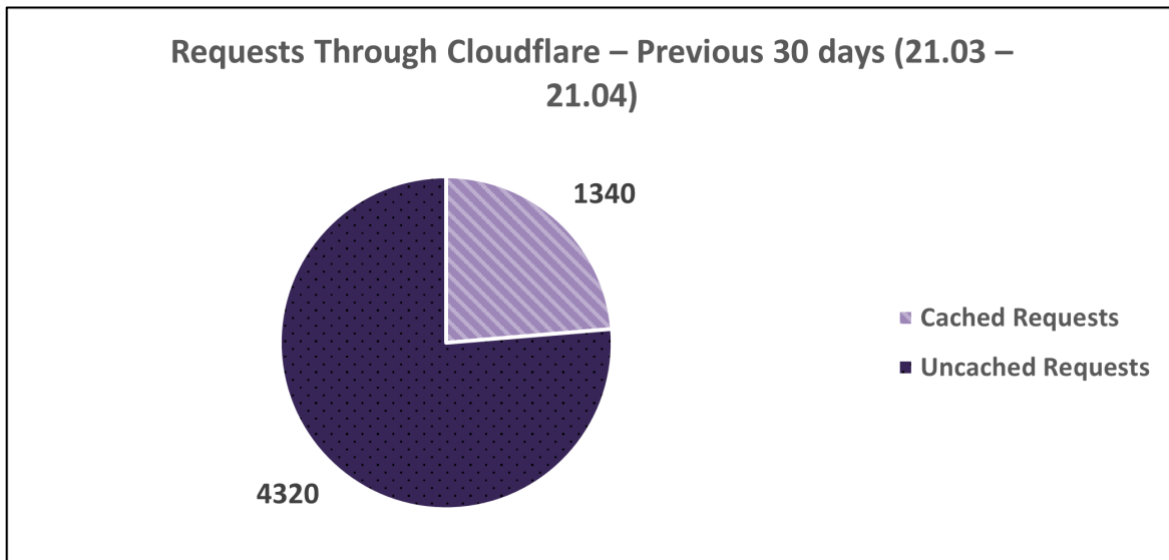


Figure 56. Request through Cloudflare.

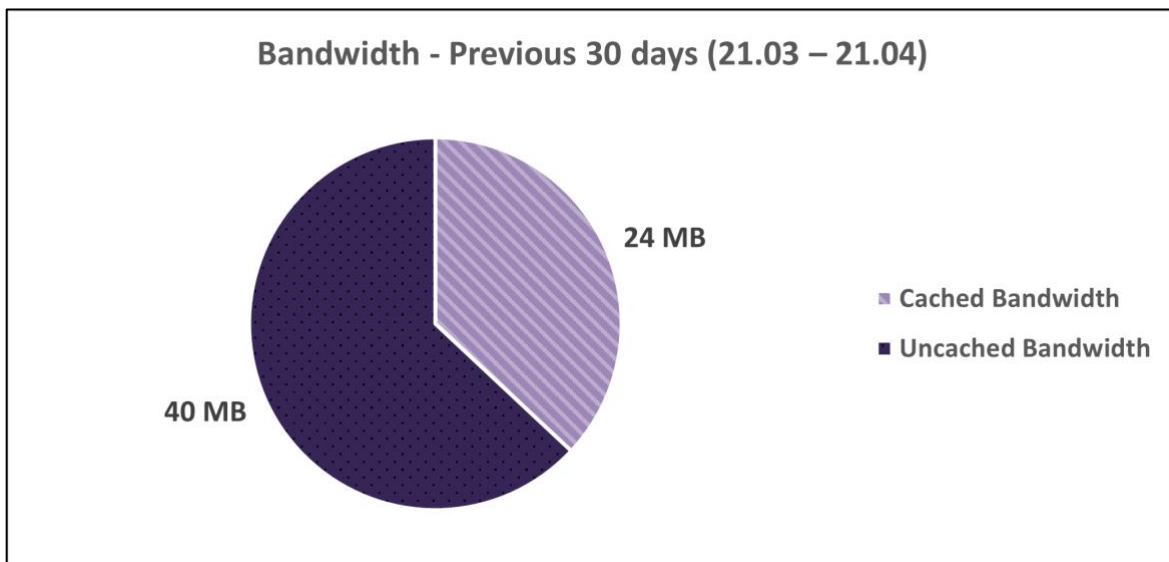


Figure 57. Bandwidth saved with Cloudflare.

### 4.5.3 Using cache

Using `sessionStorage` means the data is not fetched from the back-end again during the session. Storing data that will not often change in `sessionStorage`, reduces the number of calls to the back-end. Loading times will also be reduced as the application fetches the data instantaneously. Figure 58 displays what `sessionStorage` looks like after a user has visited the IDG2100 course and its belonging quizzes as key-value pairs.

Key	Value
fetchHomeData	{ "player": { "name": "nebula", "code": "IDG2100", "courseName": "Full..."
IDG2100_s2022	{ "player": { "name": "nebula", "code": "IDG2100", "courseName": "Full..."
IDG2100_s2022-Data	{ "kahootsInPeriod": { "title": "IDG2100Stateless_Stateful", "playedOn..."
showBarChart	true
idg2100stateless_stateful-15-1	{ "coursesInPeriod": { "code": "IDG2100", "name": "Full stack Web De..."
duplicate_of_idg2100complex_data_types-22-1	{ "coursesInPeriod": { "code": "IDG2100", "name": "Full stack Web De..."
idg2100_statelessvstateful3-1-2	{ "coursesInPeriod": { "code": "IDG2100", "name": "Full stack Web De..."
idg2100fetching_data-22-2	{ "coursesInPeriod": { "code": "IDG2100", "name": "Full stack Web De..."
idg2100redux-29-2	{ "coursesInPeriod": { "code": "IDG2100", "name": "Full stack Web De..."
duplicate_of_idg2100recap-5-3	{ "coursesInPeriod": { "code": "IDG2100", "name": "Full stack Web De..."

Figure 58. Data from the back-end saved in the `sessionStorage` property

### 4.5.4 Using optimized imagery

We can reduce the file size by converting the original PNG files to more modern file formats like WebP and AVIF. Figure 59 shows the file names and sizes for the various file formats in kilobytes. The File size reduction column compared the sizes from PNG and AVIF.

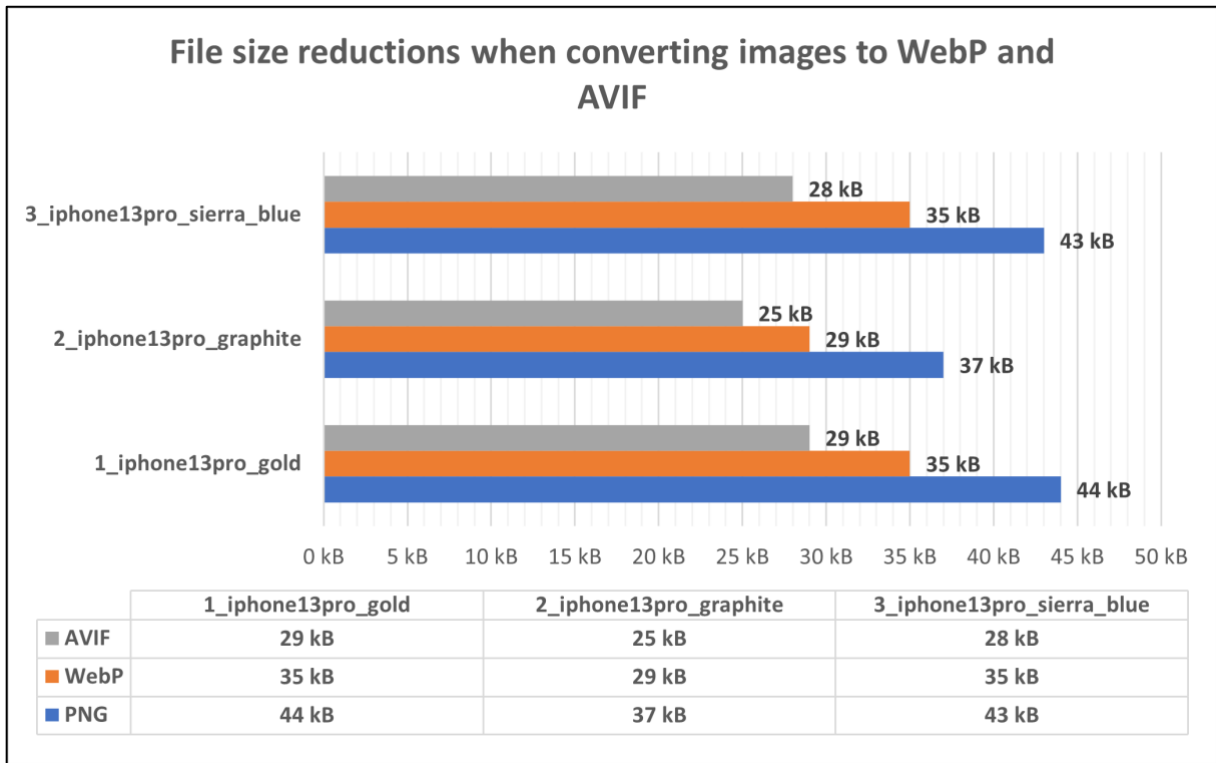


Figure 59. Savings from optimizing image files

The figure and table display a 34% average file size reduction using AVIF over PNG. If the user visits uniLeague using a browser that supports AVIF, they only download 101 kB instead of 124 kB, saving 23 kB.

### 4.5.5 Using optimized typography

By converting the original TrueType-font file to WOFF2 and subset the glyphs we will not use, the group managed to reduce the file size. Figure 60 below shows the total savings.

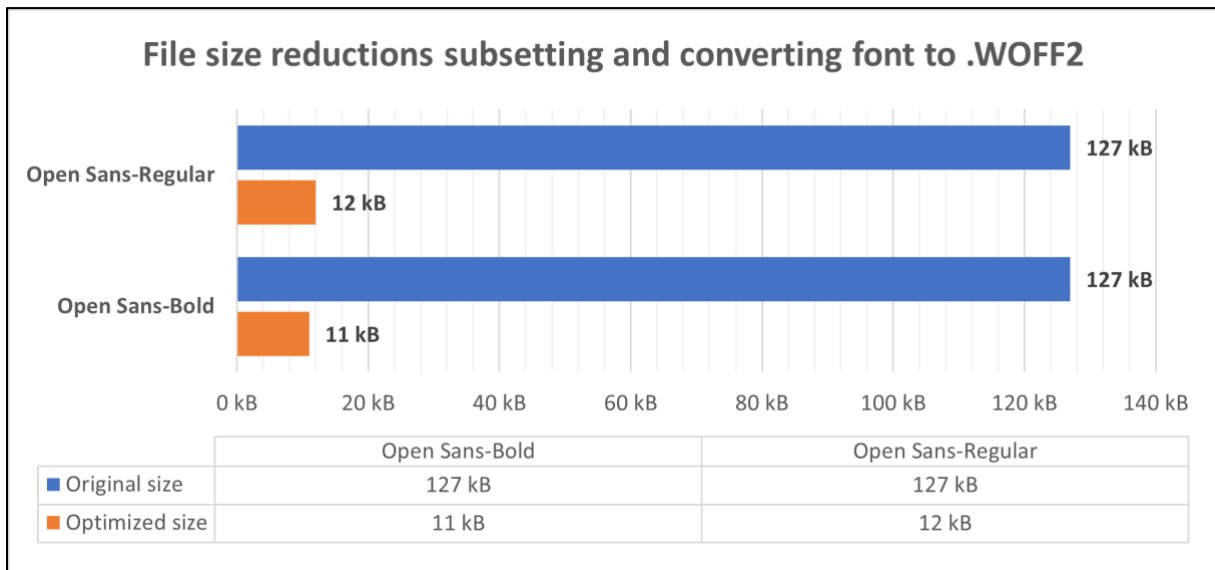


Figure 60. Savings from optimizing font files

The figure displays a file size reduction of 91%, saving 231 kB when downloading the Open-Sans font file.

#### 4.5.6 Using optimized bundle size

We removed an unnecessary npm package and reduced the bundle size by 70 KB. Using the tool “Source map explorer”<sup>30</sup> we analyzed the bundle size for uniLeague before and after the removal. In this section, we demonstrate the results of removing a redundant npm package from uniLeague. See section 3.4.6 *Optimizing bundle size*.

The original bundle size is depicted in Figure 61. A circle enlarges the total bundle size, which is 570 KB, before removing the @mui package.

<sup>30</sup> <https://www.npmjs.com/package/source-map-explorer>

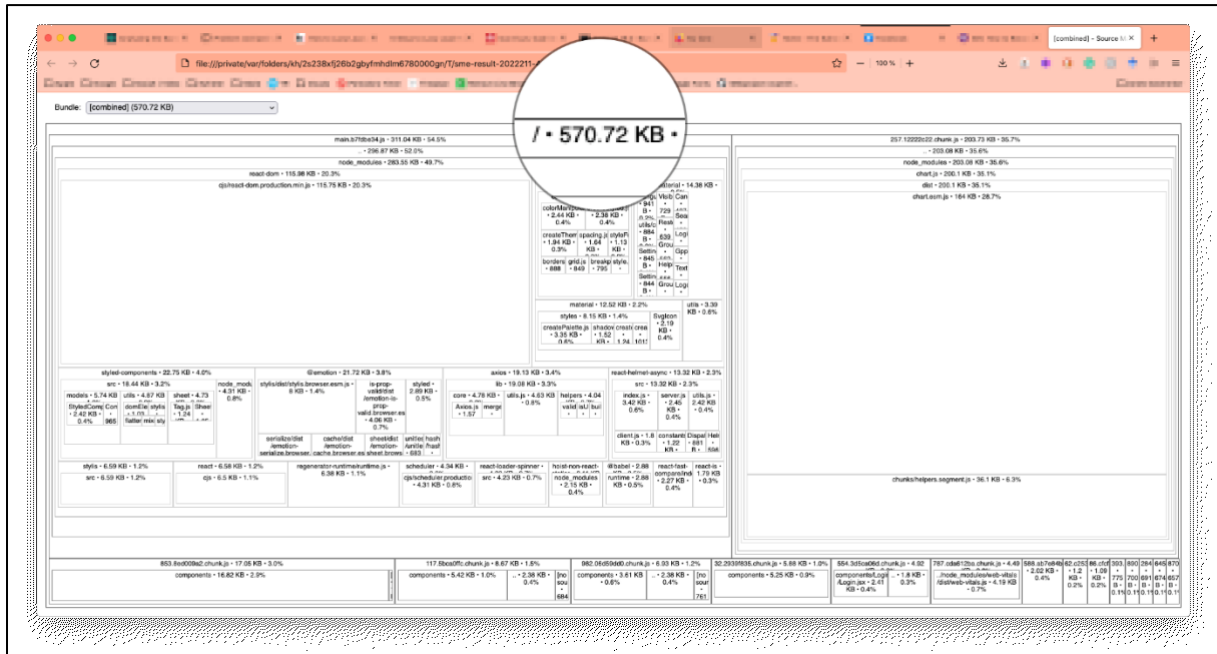


Figure 61. The total bundle size before removing the @mui package.

Figure 62 illustrates the total bundle size after removing the @mui package.

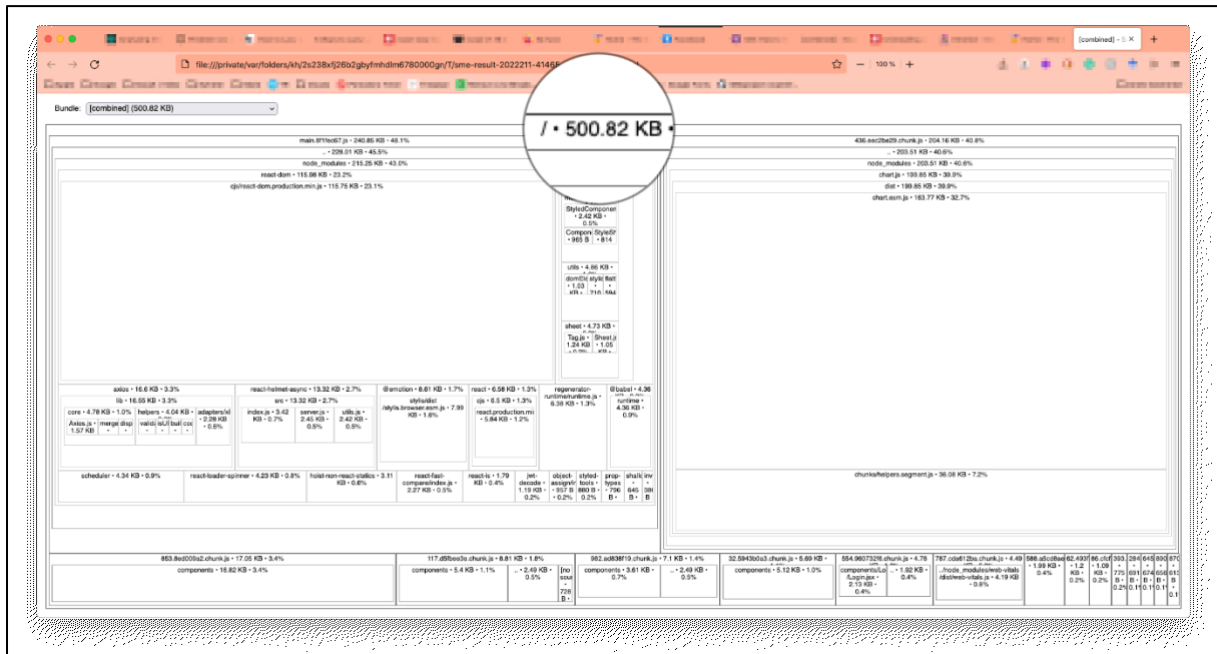


Figure 62. The total bundle size after removing the @mui package.

By comparing the bundle sizes of the two figures above, we can see how quickly we can reduce our overall bundle size by removing a redundant npm package. It decreased by 70 KB in this case.

#### 4.5.6.1 Using optimized iconography

We reduced the iconography from 69 kB to 11 kB by compressing the SVG files into an SVG sprite (A 84% size reduction) with OMGSVG and Sprite.es. See Figure 63.

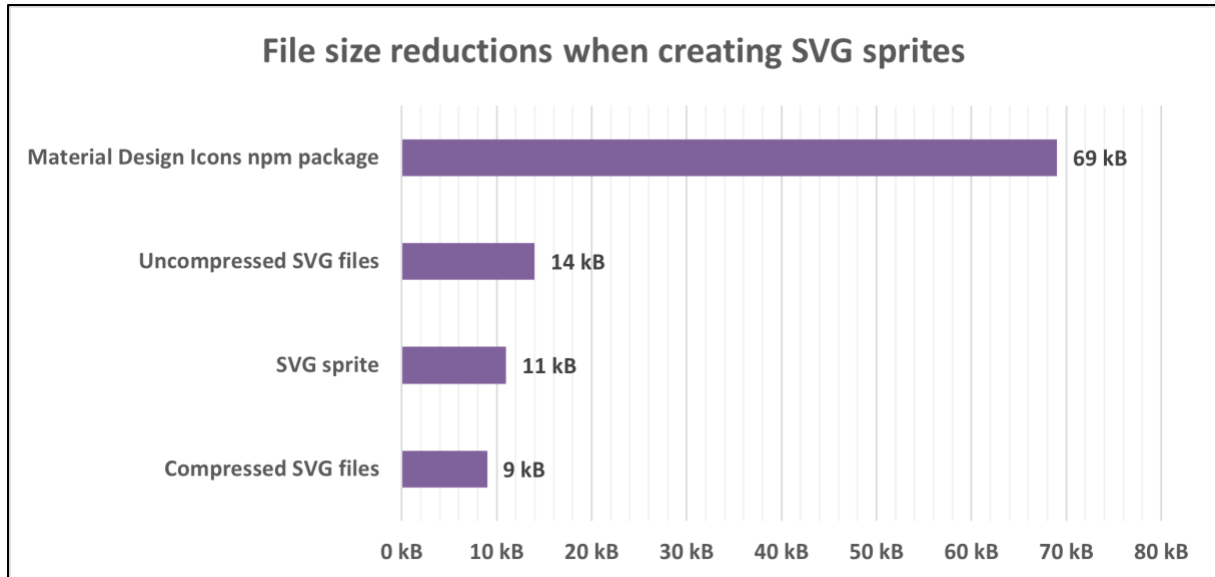


Figure 63. File savings of optimizing iconography.

#### 4.5.7 Using code splitting

Using lazy loading on the components can reduce the transfer sizes from 1400 kB to 988 kB. The time it takes to load resources has been reduced by 390ms. See Figure 64 and Figure 65.

Figure 64 shows an excerpt from the network panel in the browser before utilizing lazy loading.



Figure 64. Excerpt from the Google Chrome's network pane before using lazy loading

Figure 65 shows an excerpt from the network panel in the browser after utilizing lazy loading.



Figure 65. Excerpt from the Google Chrome's network pane after using lazy loading

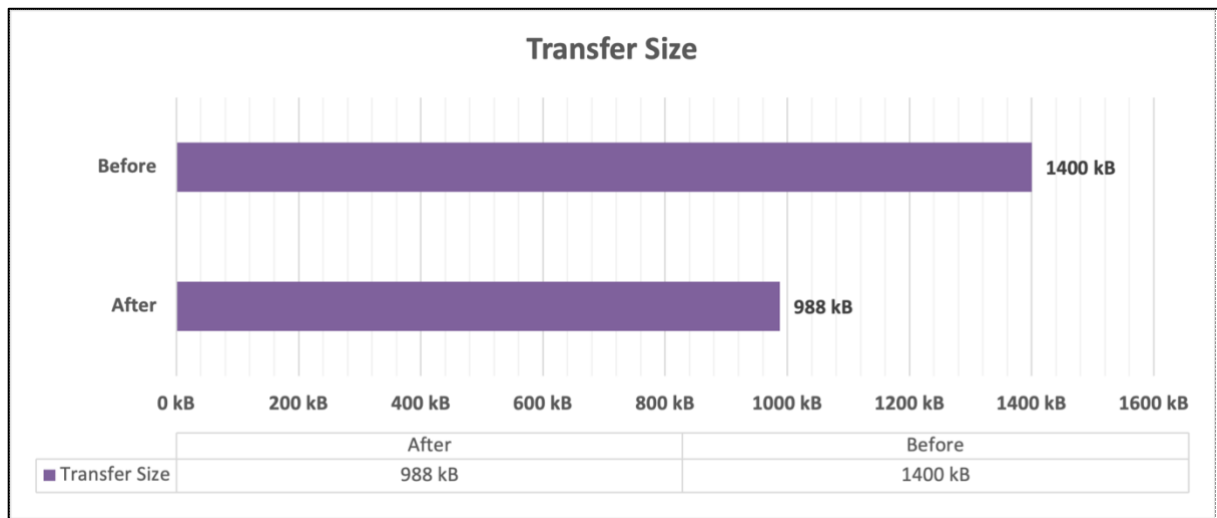


Figure 66. Graph showing before and after lazy loading

Figure 66 shows a decrease in transfer size from 1400 kB to 988 kB, a reduction of 30%.

#### 4.5.8 Bringing information to the front

The following images show what information was brought forward. We highlight how the placement was brought forward in the Figure 63. The figure also displays the number of correct and incorrect answers displayed per quiz without navigating to a specific quiz.



Figure 67. UI elements show how the information was brought forward



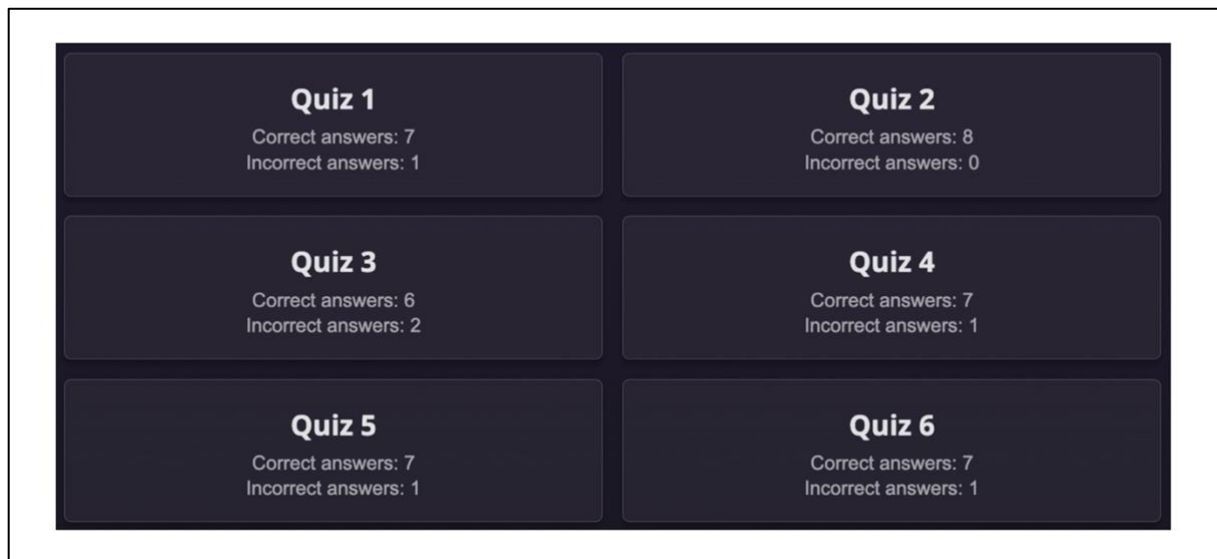


Figure 68. UI-Elements showing correct and incorrect answers for each quiz

This chapter has continued the examination of our trifold problem statement. The chapter began by presenting our web application, uniLeague. uniLeague can be considered the direct result of the front-end and the back-end.

Then, the chapter demonstrated how the design was improved based on feedback from usability tests conducted on target group participants. The group ensured that the average SUS score was greater than 68 points by administering the System Usability Scale questionnaire. As seen in section 4.2.5.2 *System usability score*, our second design iteration averaged 78.3 for the students and 83.3 for the administrators. As a result, we could conclude that our design was sufficiently usable.

Then the chapter argued that studies with a small sample size would be limited to detecting large differences or significant "effects." It suggested that using uniLeague in a class had a negligible effect on the study group's overall engagement, as determined by the Student Course Engagement Questionnaire (SCEQ). It indicated that our sample size and effect size were insufficient in our study.

Finally, this chapter demonstrated how measures implemented during the project's development phase improved uniLeague's sustainability by minimizing data transfers, directly contributing to the United Nations' 13th sustainability goal. For instance, we have seen how utilizing modern, optimized images and fonts significantly reduces the amount of data a user must download.

The result is a web page estimated to be 90% cleaner than other web pages tested on [websitecarbon.com](https://www.websitecarbon.com). The website has a page weight of about 555 kB measured from the *My*

*Results > individual course* page. Our page weight is 72.25% smaller than the average website (Greenwood, 2021, pp. 37).

The following chapter discusses the thesis. We will compare our findings to the thesis's theory and those of other researchers. Additionally, we will discuss the study's strengths and weaknesses. Lastly, the following chapter will outline the group's recommendations for additional work.

## 5 Discussion

After having described the underlying theory, the methods employed and the results achieved, we now discuss how the three problem areas of the project (*design and develop the web application, measure the engagement, and ensure sustainability*) fit together and contribute towards addressing the key problem tackled in this thesis. As the thesis addresses three problem areas, we acknowledge that it has been somewhat confusing thus far. Here is the summary and an explanation of how everything fits together.

The following problem statement was defined in section *1.3 Problem statement*:

*Does a web application displaying Kahoot!-quiz results engage students in the IDG2100 course at NTNU in Gjøvik?*

To help answer the problem statement, we divided it into three segments. These were *design and develop the web application, measure the engagement, and ensure sustainability*.

The first segment produced the web application "uniLeague," which was tested by students in the IDG2100 course. The second section addressed how we measured the students' engagement before and after using uniLeague. The final segment explained how uniLeague became sustainable. The three sections that follow will discuss the outcomes of each problem area.

### 5.1 Design and develop the web application

The first problem area, design and develop the web application, were solved by using design methods as described in 3.1 Design. The result was the web application "uniLeague," as mentioned in section *4.1 uniLeague – Web Application*.

The design and development phase outcomes do not significantly deviate from our expectations. Therefore, the results will not be thoroughly analyzed and discussed. However, we will present a suggestion for potential enhancements.

#### 5.1.1 Strengths and weaknesses

The usability test (See section 3.1.5 Conducting a usability test of the low fidelity prototype) and System Usability Scale Questionnaire (SUS) (see section 3.1.5.8 *System usability scale questionnaire*) could have been enhanced and fulfilling all the desiderata could have been completed.

##### 5.1.1.1 Usability Test

A couple of things for the usability test could have been done differently, such as different participants, more accurate timing, and having unique participants. The participants were students the project group knows, both personally and academically. In general, one should

avoid testing with people with whom one has a personal relationship, as they are likely to be overly loyal and fearful of expressing themselves negatively. Optimally, the group should have tested the design on students who do not have personal relationships as strangers are less hesitant to offer criticism (Sandnes, 2018, p. 295).

As mentioned in section 3.1.5 *Conducting a usability test of the low fidelity prototype*, the template used for conducting usability tests contained a field for timing the task for each participant. We found that the timing was inaccurate and highly inconsistent. Variations in concentration, gradual learning of a task, fatigue, and boredom are all plausible causes of the enormous variety in completion time (Sandnes, 2018, p. 308). The room used for the testing was also used by other students when conducting the usability tests. This could interfere with the testing and give unreliable results (Sandnes, 2018, p. 296).

Returning to section 2.3.6 *Usability testing*, it claimed that each user test should have five unique participants. It then was explained in section 3.1.5.6 *Finding participants*, that the second iteration of the design targeted toward administrators was only tested on one administrator and two teaching assistants.

The Nielsen Norman Group states that three to four users per target group (students and administrators in our case) is sufficient for a usability test (Nielsen, 2012). Therefore, we do not view this as a problem, even though it contradicts the abovementioned theory. Ultimately, the user experiences of the two groups will overlap. For instance, both groups were tasked with reading the leaderboard for a particular course.

#### 5.1.1.2 *SUS questionnaire*

Furthermore, after participating in the usability test, participants were urged to complete the SUS questionnaire. The questionnaire would help us calculate the SUS score for the tested prototype. However, not every participant completed the questionnaire. This might be because after the participant had scanned the QR code, the testers who conducted the usability test left the participant alone. This could make it easier for the participant not to complete the questionnaire as they were not observed anymore. However, we felt that it would be better to leave the participant alone so they could express what they felt about the prototype.

#### 5.1.1.3 *Partial implementation of desiderata 6: "additional in-class activities"*

The functionality to upload results from multiple in-class activities is not fully implemented, as mentioned in section 4.1.4 *Scalability*. The functionality for additional "in-class activities." is omitted due to the lack of time to develop new formats. Although the functionality is not implemented, a starting point for further development has been added to the database structure, see Figure 69.

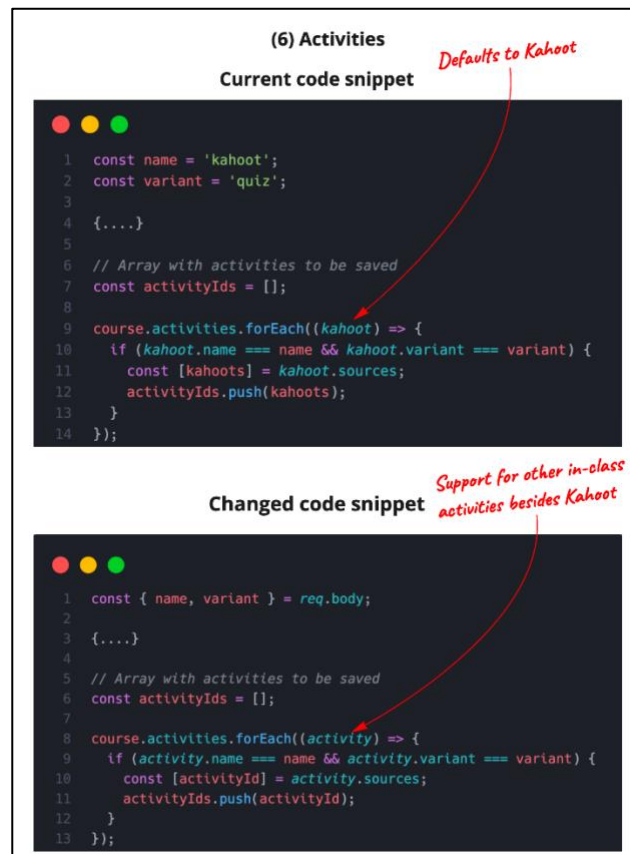


Figure 69. Current code snippet and changed code snippet showing support for other in-class activities besides Kahoot

The functionality to share results, as stated in section 4.2.1 *Competitor analysis results*, requirement number (10) Sharing results are not met. Due to time constraints, this functionality has not been a priority, and uniLeague is an MVP. The alternative would have been to implement this feature, but there would have been no way to determine whether students utilized it.

### 5.1.2 Competitor analysis

Creating a comprehensive competitor analysis was unnecessary because we are not creating anything new (see 1.5 *Project scope and limitations*). However, we had to investigate whether the product owner's wishes had been implemented in an existing solution. Section 4.2.1 *Competitor analysis results* mentions that Kahoot! EDU is a viable option, but further development and giving points for other-in-class activities that the product owner has in mind is not fulfilling the desiderata mentioned in section 1.2 *Desiderata*.

TrustRadius asserts that all reviewers are verified, it does not sell leads or paid placements, and vendors cannot manipulate search results (TrustRadius, 2015). Using TrustRadius is beneficial because we have relied on others' opinions rather than our own experiences.

Although, it is challenging to confirm that users who have reported experiences are, in fact, teachers.

#### 5.1.2.1 *Discuss the strength and weaknesses*

Blackboard Learn, Mentimeter, and Quizizz are not viable alternatives. In contrast, Kahoot! EDU appears to be a viable alternative. However, critical features such as (6) *giving points for other in-class activities besides quizzes* and (8) *further development* are not fulfilled.

Additionally, many of the necessary features are locked behind a paywall. The following features are included in Kahoot! EDU: (1) *track student and class progression*, (3) *top five students on a leaderboard*, (5) *combine reports to reduce human error*, and (7) *scale the number of users*.

We are now moving on to consider the second problem area, measuring the engagement of uniLeague in IDG2100.

## 5.2 Measure the engagement

### 5.2.1 What do the results mean considering theory?

#### 5.2.1.1 *Compared with other studies*

Section 2.4 *Engagement in the academic context* mentioned multiple studies that found a positive effect on student engagement, and some found gamification to be inefficient. The studies investigate the relationship between gamification elements such as leaderboards and their effect on student engagement. Our findings align with other studies mentioned in section 2.4 *Engagement in the academic context* regarding gamification within an academic context and its positive effect on student engagement.

Using SurveyMonkey, we determined that our data represents the class we studied (see section 4.4.4.1 *Calculating reliability*). This means that the results gathered will be outdated at the end of the semester. The next class may have different opinions on specific topics, making it hard to conclude if the results are representative for a whole semester, academic course, or even a 3-year program. Therefore, more extensive research should be conducted with a broader user group.

The generated data is most pertinent to the product owner, who must decide whether the project will be further developed or whether it should be terminated after the thesis is delivered.

The authors included a Net promoter score (NPS) in the post-questionnaire to make it easier to decide if uniLeague should be further developed based on direct feedback from the users (see section 3.3.5 *Questionnaire design*). The NPS measures customer satisfaction and forecasts business growth. The product owner should investigate the NPS before deciding whether the product should be further developed or terminated.

The current NPS for uniLeague is -41. (Distribution: 2 promoters, 3 passives, and 7 detractors) As a result, one can conclude that the students who responded to the post-questionnaire do not intend to recommend uniLeague to others. This data indicates that improvements to uniLeague are necessary. It is difficult to speculate on the nature of these improvements because no information regarding improvements or other feedback from end-users was collected.

#### 5.2.1.2 *What can we generalize?*

We can generalize that the engagement in the study group did not change significantly.

##### 5.2.1.2.1 *Failing students*

The same week we were supposed to make the post questionnaire available, a sizable portion of the students in IDG2100 failed a compulsory assignment. According to Handelsmann et al. (2010), engagement may suffer after failing a course such as the one described above. The post-questionnaire results could, therefore, be negatively distorted.

##### 5.2.1.2.2 *We only used Kahoot*

The limitation of using kahoots exclusively can have skewed the results from the engagement questionnaire in multiple ways.

One of the studies mentioned in the background cha claimed that using gamification in class positively affected student engagement. More specifically, they found that kahoots engage the student in the class (Aleksic-Maslac, Rasic, and Vranesic, 2018).

In contrast, while Kahoot appears to motivate students, it is essential to note that multiple researchers claim that the gamification impact decreases over time as the novelty wears off (i.e., the novelty effect) (Sanchez, Langer, and Kaur, 2020; Rodrigues et al., 2022; Tsay et al., 2019).

Firstly, because we only use kahoots in our study in addition to uniLeague, it is hard to determine the origin of our engagement as the SCEQ is not able to separate engagement sources (kahoots vs. uniLeague in this case<sup>31</sup>) in a course.

Secondly, the research group wonders if the novelty of Kahoot has worn off because Kahoot is also used to engage the students in the course IDG1292. All students in the sample group

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<sup>31</sup> If we disregard other class activities that the authors are unfamiliar with due to their absence from lectures.

have completed IDG1292 in the semester of fall 2020. Therefore, the sample group may not be as engaged in Kahoot as students unfamiliar with Kahoot.

The study could have conducted a questionnaire before using kahoots in class to create a "kahoots-free" engagement baseline. However, we were afraid of boring the students with the same questionnaire three times during the semester.

Another alternative would be a control group that used uniLeague with other Kahoot alternatives. We could have used another quiz tool unfamiliar to the students in the sample or based uniLeague on other in-class activities relevant to the tasks from IDG2100, such as committing code to assignments.

Another option would be to study first-year students in the IDG1292 course, as these students most likely are unfamiliar with Kahoot in a higher education context. However, the course is not held in the fall semester of 2022, making it unavailable to the research group.

### 5.2.2 Strengths and weaknesses of the study

One of the weakest sides of the study is the testing period; it should have been longer. This study was only seven weeks and was divided into two sections. The first four weeks were without the uniLeague web application. The next three were with the web application. For future research, this testing period should be extended to at least a semester, and the number of users should be increased (which is more in line with the beforementioned studies. See Aleksic-Maslac, Rasic, and Vranesic, 2018; Vaibhav and Gupta, 2014; Rojas-López et al., 2019). Tracking the traffic on the web application should also be added to see if users are using it. Lastly, the number of participants for the quizzes should be more stable to get a better sample size.

In contrast, one of the biggest strengths of this project is how we have kept the privacy of the test subjects. At no point during the project have any of the project members identified who the test subjects were. No one has been forced to participate in the study as we wanted to have the most reliable data.

We utilized self-reported data in the SECQ to evaluate students' intrinsic motivation and course engagement. However, the reliability of such data may be compromised by respondents' inability to reflect on their motivations accurately (Bowman, 2011).

The SCEQ (See section 3.3.5 *Questionnaire design*) has some subjective statements. Statements containing "good" and "do well" can be interpreted differently from student to student. These statements are #9, #12, #15 and #16 (see section 3.3.5 *Questionnaire design*). To counteract relative language, the group could have defined what it means to "do good" on a test and what it means to "get a good grade" in a course. However, the SCEQ is a tested and proven instrument to measure engagement in higher education. Additionally, as mentioned in



section 3.3.1 *Questionnaire purpose* it is recommended to measure novel pedagogies on student engagement. We, therefore, chose to trust the SCEQ.

In addition, caution is required when interpreting the findings of the current study due to the unequal gender composition of the sample (around 90% of the sample consisted of male participants). There may be a difference between men and women in terms of competition. According to a *Harvard Business Review* article, the typical woman is less competitive than the typical man (Kesebir, 2019). Men may be more competitive than women because they hold more optimistic beliefs about competition outcomes (Kesebir, 2019).

Future research could also replicate the study with a larger sample size and participants from different courses and programs at NTNU in Gjøvik. In section 4.3 *Results from development*, it was mentioned that studies with a small sample size would be limited to detecting large differences or significant “effects.”

Due to the limited course capacity, there were only 13 participants in our study sample. To increase the generalizability of the results, a larger sample size with a gender-balanced composition would be desirable.

### 5.2.3 Is more research needed?

#### 5.2.3.1 *More extensive research period & a more significant sample*

Additional research is necessary because our study lasted only seven weeks, which we believe is too short. To better understand the impact of uniLeague on students, we believe that larger sample size should be included in the study. The study period should extend throughout the semester like similar studies mentioned above (e.g., Bai et al., 2021; Vaibhav and Gupta, 2014), not just seven weeks.

Significant changes in the level of engagement are expected. The original authors of the instrument used to measure engagement state: “We also believed that students’ levels of engagement may be variable across courses and over time in a given course.” (Handelsman et al., 2010). Since our results yielded no significant change in engagement. See section 4.4 *Results from student course engagement questionnaire*, for a more extended testing period might be profitable.

#### 5.2.3.2 *Additional engagement-promoting gamification elements*

In this project, we only measured the effect of uniLeague on student engagement with the results from kahoots. We did not design gamification elements to promote student engagement. As a result, only a point system and a leaderboard were included per the product owner's desiderata.

Additional engagement-promoting gamification elements such as levels, badges, challenges, and quests (Zichermann and Cunningham, 2011) could have been investigated with a more

extensive research period. These elements could have engaged students more than the current points and leaderboards, making uniLeague a more considerable success. Additionally, it could improve the negative NPS uniLeague currently has.

#### 5.2.4 What are the implications for practice?

By using uniLeague, the product owner now has a way of tracking their students' progression through a specific course and semester. A web application has replaced the human factor of adding quiz results. This automation will save the product owner and student assistants' precious time. Students can now see their progress and position on the leaderboard, leading to more engagement in the course.

### 5.3 Ensure Sustainability

Lastly, we will cover the third and final problem area, *ensuring sustainability* of uniLeague and how it contributes to the UN.

#### 5.3.1 Contributing to UN Sustainable Development Goal 13

We have ensured that minimal data is transferred between the server and the end-user (data transfer). This is important because transferring data requires electricity, which contributes directly to climate change. By reducing data transfer and increasing energy efficiency, uniLeague contributes to UN Sustainable Development Goal 13: Climate Action. See section *2.5 Importance of Sustainable Development Goals & Sustainable web design*.

Additionally, by displaying our carbon emissions and green hosting results in the footer of uniLeague, we spread awareness of the carbon emissions connected to the Internet. Spreading awareness directly contributes to target 13.3 "Improve education, awareness-raising, and human and institutional capacity on climate change mitigation, adaptation, impact reduction, and early warning." (See section *2.5 Importance of Sustainable Development Goals & Sustainable web design*).

The measures mentioned above led us to conclude that uniLeague is 90% cleaner than the other websites examined with the same tool in section *4.5.1 Using green hosting*. How sustainable uniLeague is, however, is uncertain as only the server side has been measured. The tool mentioned in *4.5.1 Using green hosting* does not measure the client's carbon emissions; therefore, the results should be taken with a grain of salt. As Website Carbon Calculator does not state which page has been tested, we assume it is the homepage. This means that the results can be different if a page with more content and data had been evaluated.

uniLeague contained relatively limited data (only one class for one semester) when the test was conducted. The outcome may be entirely different if the test is conducted when uniLeague is being used on a larger scale with multiple classes and semesters. The amount of

data in the database and the data transferred between the back-end and the front-end will be heftier if uniLeague is used for a whole semester, academic course, or even a 3-year program.

If the project had more time, we could also have focused on energy efficiency on the client side of uniLeague as it is created with React, a client side-framework (see section 2.3.8.1 *Front-end*). Focusing on the client-side and server-side efficiency could have made uniLeague more sustainable as it would lower the energy consumption on the end-user devices and the server. uniLeague's current energy consumption in the client is unknown as no measurements have been taken during the project's duration.

### 5.3.2 Green host

Finding a green host has proven to be more difficult than anticipated. Using The Green Web Foundation's Green Hosting Directory, we looked for hosting companies that could demonstrate their green claims. While the directory lists 403 green hosting companies in 29 countries, only the six companies in Norway were examined. Servebolt was a company that piqued our interest; however, after a couple of e-mails and a meeting, hosting a web application like uniLeague was not supported by their service. As described in section 3.4.1 *Choosing a green web host*, DigitalOcean was found as a substitute.

Digital Ocean claims in a tweet, "Our renewable energy data centers are as follows: NYC1, LON1, AMS2, AMS3, and SGP1." (DigitalOcean, 2020). A quick Google search found the ones responsible for Amsterdam data center AMS3-AMS5 (interxion.com). Interxion claims on its website that "100% of our energy is from renewable sources." (Interxion, 2019). One source that supports the claim is the business case of the company Equans, which states, "With an energy-efficient cooling system, EQUANS made a significant contribution to the sustainability of Interxion's AMS3 data center in Amsterdam." (Equans, 2022). Interxion also mentions this in their factsheet, "We're committed to the use of free cooling and groundwater cooling, but never at the expense of reliability and availability." (Interxion, 2018)

We have established that our DigitalOcean "Droplet" running on the AMS3 region is hosted green. For additional confirmation that uniLeague is hosted sustainably, The Green Web Foundation's "green web check" (The Green Web Foundation, 2021) is employed. As mentioned in section 3.4.2 *Configuring the Content Delivery Network*, a CDN delivers resources from the origin server (Droplet) to proxy servers managed by Cloudflare. As a result, the "green web check" shows "Hosted by: Cloudflare" see Figure 70. Cloudflare fulfills the requirements to be considered a green host. They report carbon emission reports annually and purchase *Renewable Energy Credits* (REC) to account for the energy used by their network. Refer to (The Green Web Foundation, 2022; (Wissmann and Garbers, 2021).

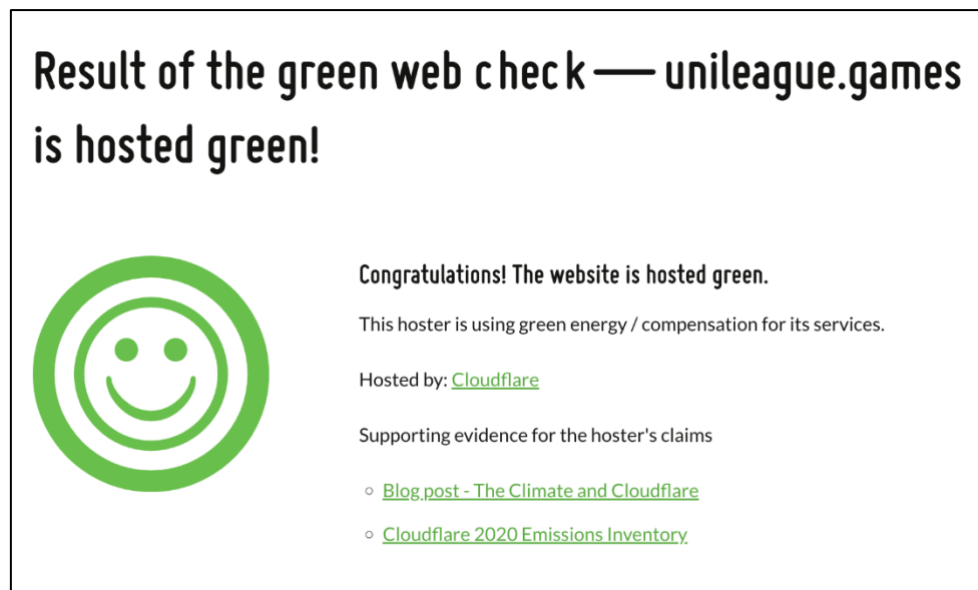


Figure 70. uniLeague's result of the [green web check](#)

## 5.4 Further development

If this project were to be further developed, the authors would recommend implementing sharing results to fulfill the product owner's desiderata. More usability testing should be conducted with users who have no relations with the project or its developers.

The sample size should be increased to acquire a more generalized result, and the testing should be conducted on first-year students as they have not used Kahoot! in university. Furthermore, a more extensive testing period over a semester, academic course, or 3-year program would be recommended. Additional engagement-promoting gamification elements such as levels, badges, challenges, and quests should be looked at to see if they can help increase the engagement.

Lastly, the sustainability of client-sided operations should be measured to further contribute to UN Sustainability Goal 13.

## 6 Conclusion

In this thesis, three different problem areas have been tackled, *design and develop a web application*, *measure the engagement*, and *ensure sustainability*. All three problem areas are related to *uniLeague*, a web application we developed used to address the question:

*Does a web application displaying Kahoot!-quiz results engage students in the IDG2100 course at NTNU in Gjøvik?*

**1. Design and develop the web application.** We designed and developed a web application called “uniLeague” utilizing the MERN-stack, competitor analysis, scenarios, wireframing, low-fidelity prototyping, user-testing, sustainability testing, and a high-fidelity prototype. See section 3.1 *Designing the web application*.

A teacher can upload quiz results to uniLeague. The web application automatically generates a class leaderboard and gives each student individual statistics regarding their quiz performance. The result is a web application that fulfills most of the product owner’s wishes. See section 4.1 *uniLeague – Web Application*.

**2. Measure the engagement.** We gathered quantitative data about the students’ engagement before and after using uniLeague with *the Student Course Engagement Questionnaire (SCEQ)*. See section 3.3 *Measuring the engagement*.

Although limited in number, our material suggests that students’ engagement was affected by using uniLeague in class. These results align with the research that says gamification in education will positively affect student engagement (See Aleksic-Maslac, Rasic, and Vranesic, 2018; Vaibhav and Gupta, 2014; Rojas-López et al., 2019)

**3. Ensure sustainability.** Throughout the design and development process, we have done measures such as choosing a green web host, setting up a CDN, caching information, optimizing imagery, typography, bundle size, code splitting, and bringing the information to the front. The measures keep uniLeague sustainable, thereby ensuring that uniLeague directly contributes to UN’s 13<sup>th</sup> Sustainable Development Goal, “Climate Action.”

The measures mentioned above resulted in 34% smaller image file sizes, 91% smaller font sizes, optimized bundle sizes, split code for each route, cached data to reduce server requests, and bringing information to the front, minimizing page loads. The green host (DigitalOcean)

ensures our server uses renewable energy on the server. The result is a web page that is 90% cleaner than other websites tested on website carbon<sup>32</sup>. See section 4.5.1 *Using green hosting*.

All three problem areas contributed to answering the question:

*Does a web application displaying Kahoot!-quiz results engage students in the IDG2100 course at NTNU in Gjøvik?*

Our results show that a web application displaying Kahoot!-quiz results will positively increase, although to a little extent, the engagement of students of the IDG2100 Full-Stack Web Development. However, based on the small sample size and testing period, we cannot say for certain that uniLeague will increase student engagement for a whole semester, academic course, or even a 3-year program.

Therefore, the authors suggest that the project should be further developed because uniLeague has the potential to engage students, especially first-year students.

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<sup>32</sup> <https://www.websitecarbon.com/>

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# Appendix 1: Introductory meeting with the product owner

## Questions

What is the problem today, and how did it arise?

The context is specific to IDG1292. Everything started in that project. The same kind of model could be applied to different subjects. We have students with different ambition levels. Kahoot is an excellent way to (unintelligible). Feedback is positive, and we are doing it today. Turning this into a league would be more motivating. Weekly motivation, First step within gaming strategies (unintelligible).

How is the situation today? What is the product owner doing now to get an overview of all the scores for the students?

He is using Kahoot, but the ambition is to replace it with Mentimeter or any other platform.

He will play the Kahoot and download the file, he sorts the columns alphabetically. The excel-file is divided into a tab with summary and questions with score.

Why do we want to do something about it?

Motivation to solve this situation is efficiency, taking up a lot of Carlos's time and TA time. Easy to make mistakes (remove human). Increasing the level of engagement from students. Maybe send notifications to students, (hey you are rank ...).

We need to think about how we invite users to the system, what the ambition level is (Competition on various levels?), terms of service (agreement on sharing information), maybe add functionality for sharing scores in social media.

Who are the stakeholders / affected in the problem?

The problem exists for teachers and teaching assistants as they must do the job manually. However, the solution would be for everyone (students, student/teaching assistants and teachers)

Are we creating something completely new? Or should we improve an existing product?

Not to his recollection.

What defines success in relation to the product?

Something that works. He measures success based on the number of users that are visiting, sharing results and scores, and how many teachers that want to use the platform. It is our job to set measures or indicators that can measure this.

What do you want to achieve, and what will be the end product?

A web solution that is easy to maintain and develop, and it needs to be scalable in terms of adding new “modules” or functionality.

## Things to do

Establish agreement for communication? Should we keep in touch by email or teams? Any future meetings that can be planned already?

Teams is a workable solution, check his calendar to see if he is available before making a request. He wants a meeting time notification and the agenda for the meeting so he can prepare for the questions.

Obtain dummy data

Glenn has access to data from IDG1292, the subject in question

Other

The focus of the platform is to be engaging and learning for students. We should focus on the gamification. Look at it as modules instead. Keep in mind that it can be scaled to span multiple courses, semesters, and classes, even years. Be open to more methods to obtain points (covers, participation etc...) and have an interface for calculating scores.

# Appendix 2: Personas from previous work

Profilbillede	Demografisk data	Bakgrund: Kort beskrivelse af livshistorien	Motivationer: Hvorfor trenger personen å bruke produktet/gjenesten?	Frustrasjoner: Hva får persona til å føle seg frustrert eller irritert over produktet/gjenesten?	Ideell opplevelse / mål / ambisjoner / følelser:	Størst Oppsummer personens opplevelse
	<p><b>Navn</b> James Everett</p> <p><b>Occupation</b> Associate Professor ved NTNU - ID-lab/teknisk</p> <p><b>Age</b> 53</p> <p><b>Gender</b> Mann</p>	<p>James har bodd og oppvokst i USA, San Francisco. Han fikk tidlig en kjærlighet for datamaskiner og hvordan de fungerte. Allevet på tidlig 50-årene hadde James laget sin første nettside ved bruk av enkel HTML. Dette på merkevare og han ble berørt seg for å studere webutvikling. Etter han var ferdig med mastergraden, jobbet han i et institusjon for utdanning og deretter i et selskap for NTNU og ble en prof. Da ble han utvalgt for NTNU og ble en av de første assosierte professorer. Gjensidig, videre ble James også studierapporter for Bachelor Web Utvikling.</p>	<p>James underveier lager IDCI100 - Fullstack webutvikling og bruker Kahoot! skole i undervisningen for å få studentene mer engasjert i laget. Det James nå gjøre i foramt av quizen er å lage relevante spørsmål til hva studentene har lært i forelesningen. Etter quizen må James laste ned quizresultatene, sortere i resultatene, ravelogge og laste opp på systemet. Dette er et veldig tidkrevende prosess som James egentlig ikke har tid til. Det handler han om å hjelpe fra student assistentene, men er ikke alltid de har tid heller. Derfor ønsker James et produkt som kan hjelpe si med sammenhengingen av resultatene.</p>	<p>James liker ikke konkurransen og vil ikke være seg ut da han er utvokstingsstudent. Han vil forholde seg anonym, men har ikke noe problem med at resultatene blir fremvist til andre studenter.</p>	<p>Det ideelle opplevelsen for James er et verktøy hvor han kunne: 1. Laste opp dokumentet han bruker med fra Kahoot!, velknyttet til de sammenligge dem oppgjørstede. Han med databasen og legge til der det skal. 2. se en komplett resultatliste med brukere og antall poeng brukeren har 3. velknyttet til de sammenligge dem oppgjørstede. Han med databasen og legge til der det skal. 4. alle studenter sin resultater og hvordan hans egen fremgang er, men at hans egen fremgang skal vises først.</p>	<p>"Jeg som skal hjelpe meg med å håndtere oppgaver vil gjøre hverdagen min enklere."</p>
	<p><b>Navn</b> Armin Eitzner</p> <p><b>Alder</b> 28</p> <p><b>Kjønn</b> Mann</p>	<p>Armin er en undervisningsassistent på NTNU og er utvokstingslær. Han gikk bachelor i webutvikling og lærte IDCI100. Full stack webutvikling denne uken. Han er interessert i å lære mer om fullstack utvikling med hovedfokus på frontend.</p>	<p>Armin er en oppgave orientert person som liker å se et mål for seg selv og gjøre med disse. Armin har noe erfaring med Kahoot! quiz, men si nå så har han positiv opplevelse med quiz som gir han ikke tid til å lage.</p>	<p>Armin har 18 frustrasjoner med datagris system. Han har oppgaver som han må gjøre og vil ikke være seg ut da han er utvokstingsstudent. Han vil forholde seg anonym, men har ikke noe problem med at resultatene blir fremvist til andre studenter.</p>	<p>Den ideelle opplevelsen for Armin er et verktøy som: 1. Viser fremgang 2. Mulighet for å legge opplysninger og sette mål i underveik 3. Har vil gjøre kunne se hvor mange svar han har fått og hvor mange har gitt 4. alle studenter sin resultater og hvordan hans egen fremgang er, men at hans egen fremgang skal vises først.</p>	<p>"Jeg ønsker å være best. Det betyr å være i toppen og gi meg en drømme til å være med. Jeg tror det er en drømme å konkurrere med andre og vinne."</p>
	<p><b>Navn</b> Mathias Malmadal</p> <p><b>Alder</b> 20</p> <p><b>Kjønn</b> Kvinne</p>	<p>Mathias har gått ut på folkehøgskole og sett et arbeidsstadium i 11. Men senere på med skolearbeid på NTNU for å studere mer med mastergrad. Han tar nå IDCI100 - Full stack webutvikling. Han er interessert i å lære mer om fullstack utvikling med hovedfokus på frontend.</p>	<p>Mathias har et mål om å lære mer om HTML og CSS og utvikle seg som utvikler. Han har et mål om å lære mer om frontend og utvikle seg som utvikler. Han har et mål om å lære mer om frontend og utvikle seg som utvikler.</p>	<p>Mathias har 18 frustrasjoner med datagris system. Han har oppgaver som han må gjøre og vil ikke være seg ut da han er utvokstingsstudent. Han vil forholde seg anonym, men har ikke noe problem med at resultatene blir fremvist til andre studenter.</p>	<p>Den ideelle opplevelsen er et verktøy der hun kunne: 1. Sette opp egne mål 2. Se sin egen fremgang overfor andres poengsum.</p>	<p>"Det er rime å lære, det hadde vært interessant å kunne følge med på som egen fremgang, nå det gjelder mitt tekniske kunnskap i emner."</p>

Figure 71. Appendix 2: Personas from previous work

## Appendix 3: Scenario

Table 11. Appendix: 3 Scenarios

Hvem	Kontekst	Story	Hendelse	Tenkt fremgangsmåte	Problemer som kan oppstå underveis
<b>Super admin</b>	Det er et nytt år og nye studenter må legges til i en studieplan, super admin må legge til de nye studentene i uniLeague.	Som super admin vil jeg legge til studenter i en studieplan slik at de kan se de quizzer de skal gjennomføre i løpet av studiet.	Brukere	<ol style="list-style-type: none"> <li>1. Gå til nettsiden</li> <li>2. Logg inn</li> <li>3. Gå til admin-siden</li> <li>4. Gå til manage users</li> <li>5. Last opp en fil med studenter</li> </ol>	Det er allerede studenter som er lagt til i studieplanen med samme brukernavn. Filen som blir lastet opp har feil formatering.
<b>Super admin</b>	Det er mange av studentene som har droppet ut, super admin vil fjerne disse studentene	Som super admin vil jeg ha mulighet til å fjerne brukere fra en studieplan, slik at utdaterte studenter ikke fyller ledertavlene	Brukere	<ol style="list-style-type: none"> <li>1. Gå til nettsiden</li> <li>2. Logg inn</li> <li>3. Gå til admin-siden</li> <li>4. Gå til manage users</li> <li>5. Slett en student</li> </ol>	Studenten som skal bli slettet har allerede blitt fjernet fra studieplanen. Det er vanskelig å finne studenten som skal slettes.



<b>Super admin</b>	Det er mange fag som skal legges til en studieplan , super admin vil kunne opprette og legge til fagene i en studieplan	Som super admin vil jeg opprette og legge til fag i en studieplan	Opplastning	<ol style="list-style-type: none"> <li>1. Gå til nettsiden</li> <li>2. Logg inn</li> <li>3. Gå til admin-siden</li> <li>4. Gå til manage courses</li> <li>5. Legge til eller slette fag</li> <li>6. Velg studieplan</li> </ol>	Den valgte studieplanen har allerede faget lagt til på valgt semester Det er vanskelig å finne studieplanen som skal ha fag
<b>Lærer</b>	Læreren er nettopp ferdig med å gjennomføre quiz og har lastet ned resultatene til Excel	Som lærer vil jeg laste opp et Excel-ark som inneholder quiz-resultater fra emnet jeg foreleser i slik at jeg slipper å behandle resultatene selv.	Opplastning	<ol style="list-style-type: none"> <li>1. Gå inn på nettsiden</li> <li>2. Logg inn</li> <li>3. Last opp dokument ved å trykke på last opp-ikonet som er i navigasjonsbaren</li> <li>4. Når filen er opplastet velger læreren hvilket kull og semester quizen tilhører</li> <li>5. Ferdig</li> </ol>	Filen som skal lastes opp er korrupt, læreren får feilmelding men skjønner ikke hvorfor Det har allerede blitt lastet opp en quiz med samme navn så man får feilmelding
<b>Lærer</b>	Læreren legger	Som lærer vil jeg ha	Opplastning	<ol style="list-style-type: none"> <li>1. Gå inn på nettsiden</li> <li>2. logge inn</li> </ol>	Filen som blir lastet

	merke til at han lastet opp forrige ukens quiz ved et uhell. Denne quizen vil læreren slette	mulighet til å endre mine opplastninger slik at jeg kan rette opp tidligere småfeil ved opplastning.		<ol style="list-style-type: none"> <li>3. gå til admin-siden</li> <li>4. gå til mine opplastninger</li> <li>5. slette en opplastning</li> <li>6. ferdig</li> </ol>	opp er også feil så man må laste opp på nytt Feil quiz blir slettet, så man må laste opp to filer
<b>Lærer</b>	Jeg har et fag som består av studenter som går på forskjellige studier og forskjellige årstrinn. Selv om studentene er forskjellige, så ønsker jeg å holde samme quiz med alle.	Som lærer vil jeg se hvem som har flest poeng innenfor et emne (Et emne har flere quizer og består av webutvikling (3. året), interaksjonsdesign (2. året) og grafisk design (2.året)) slik at studentene mine blir mer engasjert i faget.	ledertavle	<ol style="list-style-type: none"> <li>1. Gå inn på nettsiden</li> <li>2. logge inn</li> <li>3. gå til ledertavlenvelge emne+semester du vil se</li> <li>4. ferdig</li> </ol>	Det er ingen data som blir vist Dataen som blir vist har ikke blitt oppdatert
<b>lærer</b>	Det nærmer seg semesterslutt og jeg ønsker å belønne	Som lærer vil jeg se hvem som samlet flest poeng i løpet av et semester slik	ledertavle	<ol style="list-style-type: none"> <li>1. Gå inn på nettsiden</li> <li>2. logge inn</li> <li>3. gå til ledertavlen</li> <li>4. velge semester du vil se (viser bare quizeren)</li> </ol>	Det er ingen data som blir vist Dataen som blir vist har

	studentene mine som har gjort en god insats	at disse kan få en belønning.		admin/læreren har lastet opp) 5. ferdig	ikke blitt oppdatert
<b>lærer</b>	Jeg har nettopp lastet opp en ny quiz til The Kahoot! League og ønsker å se hele ledertavlen til denne quizen.	Som lærer vil jeg se hvem som samlet flest poeng i den nyeste quizen jeg har avholdt slik at jeg kan se hvilke studenter som følge med godt i forelesningen.	ledertavle	1. Gå inn på nettsiden 2. logge inn 3. gå til ledertavlen 4. velg semester + emne 5. velg en enkelt-quiz 6. ferdig	Det er ingen data som blir vist Dataen som blir vist har ikke blitt oppdatert
<b>lærer</b>	Studentene som jeg har fult med på de siste tre årene er snart ferdig med bachelor og de som har lagt inn ekstra insats fortjener en premie	Som lærer vil jeg se hvem som samlet flest poeng i løpet av et hele studiet (1. året, 2. året og 3. året) slik at jeg kan belønne de og oppmuntre de til å stå på hele studiet.	ledertavle	1. Gå inn på nettsiden 2. logge inn 3. gå til ledertavlen 4. velge kull 5. ferdig	Det er ingen data som blir vist Dataen som blir vist har ikke blitt oppdatert
<b>Student</b>	Det er midt i semesteret og det har	Som student vil jeg kunne se en oversikt over hvordan	Ledertavle	1. Gå inn på nettsiden 2. logge inn 3. gå til ledertavlen	Det er ingen data som blir vist

	blitt gjennomført et par quizer i emnet. Studenten vil gjerne se hvor de ligger på ledertavlen i hele emnet, uansett klasse	jeg ligger i et emne		<ol style="list-style-type: none"> <li>4. velge emne du vil se</li> <li>5. ferdig</li> </ol>	Dataen som blir vist har ikke blitt oppdatert
<b>Student</b>	Det er midt i semesteret og det har blitt gjennomført et par quizer i emnet. Studenten vil gjerne se hvor de ligger på ledertavlen i hele emnet, med bare sin egen klasse	Som student vil jeg kunne se en oversikt over hvordan jeg ligger an i forhold til klassen min	Ledertavle	<ol style="list-style-type: none"> <li>1. Gå inn på nettsiden</li> <li>2. logge inn</li> <li>3. gå til ledertavlen</li> <li>4. velg klassen</li> <li>5. ferdig</li> </ol>	Det er ingen data som blir vist Dataen som blir vist har ikke blitt oppdatert
<b>Student</b>	Det er midt i semesteret og det har blitt gjennomført et par quizer i emnet. Studenten vil gjerne se hvor de ligger på ledertavlen i hele emnet, med bare sin egen klasse	Som student vil jeg se resultatene mine i et emne	Resultater	<ol style="list-style-type: none"> <li>1. Gå inn på nettsiden</li> <li>2. logge inn</li> <li>3. gå til Mine Resultater</li> <li>4. velge emne du vil se</li> </ol>	Det er ingen data som blir vist Dataen som blir vist har ikke blitt oppdatert

	<p>ørt noen quizer i emnet. Studenten ønsker å se hvordan de selv ligger an i dette emnet, men bryr seg ikke om andre i klassen eller noe ledertavle</p>			5. ferdig	vist har ikke blitt oppdatert
<b>Student</b>	<p>Det er midt i semesteret og det har blitt gjennomført noen quizer i flere av emnene studenten deltar i. Studenten ønsker nå å se hvordan de ligger an når det gjelder alle quizene</p>	<p>Som student vil jeg se alle resultatene mine dette semesteret</p>	Resultater	<ol style="list-style-type: none"> <li>1. Gå inn på nettsiden</li> <li>2. logge inn</li> <li>3. gå til Mine Resultater</li> <li>4. velge semester du vil se</li> <li>5. ferdig</li> </ol>	<p>Det er ingen data som blir vist Dataen som blir vist har ikke blitt oppdatert</p>

	dette semesteret				
<b>Student</b>	Det har gått to år siden studenten startet på NTNU. De har deltatt med mange quizer både på første året og på andre året. De vil så se på hvordan de har gjort det de siste to årene	Som student vil jeg se alle resultatene mine gjennom hele studietiden	Resultater	<ol style="list-style-type: none"> <li>1. Gå inn på nettsiden</li> <li>2. logge inn</li> <li>3. gå til Mine Resultater/velg studiet/kull du vil se</li> <li>4. ferdig</li> </ol>	Det er ingen data som blir vist Dataen som blir vist har ikke blitt oppdatert
<b>Student</b>	Studenten har deltatt på flere quizer i studietiden og har dermed fått mange riktige svar. Studenten vil nå se den samlede summen	Som student vil jeg kunne se min totale poengsum	Resultater	<ol style="list-style-type: none"> <li>1. Gå inn på nettsiden</li> <li>2. logge inn</li> <li>3. gå til Mine Resultater</li> <li>4. velg hva du vil se (emne/semester/grad)sum vises et sted på siden</li> <li>5. ferdig</li> </ol>	Det er ingen data som blir vist Dataen som blir vist har ikke blitt oppdatert

	av alle poengene de har samlet på hittil.				
<b>Student</b>	Det er midt i semesteret og det har blitt gjennomført noen quizer i flere av emnene studenten deltar i. Studenten ønsker nå å se hvordan de ligger an når det gjelder alle quizene dette semesteret, gjerne med en trendlinje	Som student vil jeg kunne se min progresjon gjennom et semester	Resultater	<ol style="list-style-type: none"> <li>1. Gå inn på nettsiden</li> <li>2. logge inn</li> <li>3. gå til Mine Resultater</li> <li>4. velg semester</li> <li>5. skru på trendlinje</li> <li>6. ferdig</li> </ol>	Det er ingen data som blir vist Dataen som blir vist har ikke blitt oppdatert
<b>Student</b>	Det er midt i semesteret og det har blitt gjennomført noen quizer i	Som student vil jeg kunne sette mine egne mål innenfor et emne	Resultater	<ol style="list-style-type: none"> <li>1. Gå inn på nettsiden</li> <li>2. logge inn</li> <li>3. gå til Mine Resultater</li> <li>4. velg emne</li> <li>5. legg til mål (et tall)</li> <li>6. ferdig</li> </ol>	Det er ingen data som blir vist Dataen som blir vist har

	emnet. Studenten ønsker å se hvordan de selv ligger an i dette emnet, i forhold til et pre-definert mål de har satt seg selv				ikke blitt oppdatert
<b>Student</b>	Studenten har gått et par år på NTNU. Studenten ønsker nå å se hvordan de ligger an når det gjelder alle quizene dette skoleåret, gjerne med en trendlinje	Som student vil jeg kunne se min progresjon gjennom et skoleår	Resultater	<ol style="list-style-type: none"> <li>1. Gå inn på nettsiden</li> <li>2. logge inn</li> <li>3. gå til Mine Resultater</li> <li>4. elg skoleår (høst+vår semester)</li> <li>5. skru på trendlinje</li> <li>6. ferdig</li> </ol>	Det er ingen data som blir vist Dataen som blir vist har ikke blitt oppdatert
<b>Student</b>	Studenten nærmer seg en ferdig utdanning og har	Som student vil jeg kunne se min progresjon gjennom hele studieperioden	Resultater	<ol style="list-style-type: none"> <li>1. Gå inn på nettsiden</li> <li>2. logge inn</li> <li>3. gå til Mine Resultater</li> <li>4. velge studiet/kull du vil se</li> </ol>	Det er ingen data som blir vist Dataen som blir



	deltatt på mange quizer, studneten ønsker gjerne å se hvordan de har gjort det på quizer i løpet av studietiden sin.			5. skru på trendlinje 6. ferdig	vist har ikke blitt oppdatert
<b>Student</b>	Det er midt i semesteret og studenten har deltatt på en del quizer i emnet de tar. De er ofte en av de beste i klassen og ønsker å vite hvor mange ganger de endte opp på pallen	Som student vil jeg se antall ganger jeg har hatt pallplass i en quiz i et emne	Resultater / mål	1. Gå på nettsiden 2. logg in 3. Gå til Mine Resultater 4. Velg emne 5. Se antall ganger du har endt opp på en palleplass	Det er ingen data som blir vist Dataen som blir vist har ikke blitt oppdatert
<b>Student</b>	Det er midt i semesteret og studenten har deltatt på en del	Som student vil jeg se antall ganger jeg har hatt pallplass i en quiz i løpet av studietiden	Resultater / mål	1. Gå på nettsiden 2. logg in 3. Gå til Mine Resultater 4. Velg kull	Det er ingen data som blir vist Dataen som blir vist har

	quizer i emnene de tar. De er ofte en av de beste i klassen og ønsker å vite hvor mange ganger de endte opp på pallen i løpet av hele studietiden sin.			5. Se antall ganger du har endt opp på en palleplass	ikke blitt oppdatert
--	--	--	--	--	----------------------

## Appendix 4: System usability score questionnaire

Table 12. Appendix 4: System usability score questionnaire-

	<b>Strongly Disagree</b>	<b>Disagree</b>	<b>Indifferent</b>	<b>Agree</b>	<b>Strongly Agree</b>
<b>I think that I would like to use this sytem frequently.</b>	1	2	3	4	5
<b>I found the system unnecessarily complex.</b>	1	2	3	4	5
<b>I thought the system was easy to use.</b>	1	2	3	4	5
<b>I think that I would need the support of a technical person to be able to use this system.</b>	1	2	3	4	5
<b>I found the various functions in this system were well-integrated.</b>	1	2	3	4	5
<b>I thought there was too much inconsistency in this system.</b>	1	2	3	4	5
<b>I would imagine that most people would learn to use this system very quickly.</b>	1	2	3	4	5
<b>I found the system very cumbersome/awkward to use.</b>	1	2	3	4	5
<b>I felt very confident using the system.</b>	1	2	3	4	5
<b>I needed to learn a lot of things before I could get going with this system.</b>	1	2	3	4	5

## Appendix 5: E-mails sent to customer support

### Quizizz

#### Sent

Hello! I am interested in the analytical tool your service provides. What are the key features

I want to know the features regarding analyzing the quiz results. for instance, if I have multiple quizzes in a course, am I able to group the results so I can have a leaderboard

#### Received

*Thank you for reaching out to Quizizz.*

*Quizizz is a gamified student engagement platform that offers multiple features to make a classroom fun, interactive and engaging.*

*As a teacher, you can conduct formative assessments, assign homework, and have other interactions with your students (for all grades) in a captivating way.*

*Here are some of the features offered on our platform:*

*Instructor paced lessons/Quizzes: Teachers control the pace; the whole class goes through each question together.*

*Student paced lessons/Quizzes: Students progress at their own pace and you see a leaderboard and live results for each question or lesson.*

*Bring Your Own Device (BYOD): Students always see the content on their own devices, be it PCs, laptops, tablets, or smartphones.*

*Access to millions of Quizzes: Import any public quiz as-is, edit and customize them. Teleport and Combine Quizzes is a life saviour.*

*(Quiz + Lesson) Editor: Choose from 5 different question types to add images, video, and audio to teleporting questions from other quizzes and lessons. Explore more about it using this: [LINK](#).*

*Reports: Get detailed class-level and student-level insights for every quiz. Share with parents/guardians to monitor student progress. This article will give you a detailed explanation about Reports.*

*Options to Customise: Options to customize your quiz sessions to toggle the level of competition and speed.*

*Sharing & Collaboration: Share your quiz with other instructors and/or ask them to be collaborators. You can read on Share Access with other Teachers.*

*We have a dedicated Help Center which will help you get started on Quizizz. You can visit the same from this: [LINK](#)*

*Do let us know if you have any questions. We'd be super happy to help you!*

*Regards,*

*Team Quizizz*

## Mentimeter

### Sent (1/2)

Hello! I am interested in the analytical tool your service provides. What are the key features

I want to know the features regarding analyzing the quiz results. for instance, if I have multiple quizzes in a course, am I able to group the results so I can have a leaderboard

### Received (1/2)

*Mentimeter: No, I'm afraid it's not possible to merge presentation results, at the moment.*

### Sent (2/2)

can you download the result?

### Received (2/2)

*Sure, you can download the results as PDF or as an Excel sheet.*

*This is how you can export your presentation:*

*After which, you can choose to download and print the results of the entire presentation in an excel file (paid plans), screenshots of results from individual questions, or an entire PDF.*

*More information:*

*Presentation PDF and screenshots*

*Export your results in an entire PDF or individual screenshots*

*For paid accounts:*

*Export results to Excel*

*How to export the voting results to Excel and what information you find in the spreadsheet.*

## Kahoot

### Sent (1/2)

Hello! I am interested in the analytical tool your service provides. What are the key features I want to know the features regarding analyzing the quiz results. for instance, if I have multiple quizzes in a course, am I able to group the results so I can have a leaderboard

### Received (1/2)

*Hi there!*

*Thanks for reaching out! I'm happy to hear that you're interested in using Kahoot! at School. You can access to a free trial on our web page when you sign in. If you want us to make a Zoom Meeting we are happy too! Let me know.*

### Sent (2/2)

Hello!

I am currently trying out the Kahoot! premium + for the higher education plan that Kahoot is offering. I got a couple of questions regarding inviting students via mail to join a course. I have 30 students that are attending my course and would like to have them use their own accounts, in this way I can run a Kahoot! they will then join with their user and predefined nickname. At the end of the semester, I would like to combine all the reports from the quizzes I have done to share a leaderboard with my students. My problem at this moment is that when I combine reports from previous quizzes, I notice that a lot of my students are using inconsistent nicknames and sometimes use case-sensitive nickname variants and sometimes they use either space in front or behind their nickname. This results in a lot of work when I must manually combine points. Is this a feature that Kahoot! is offering that I have missed out on? I have tried to browse the help center but couldn't find anything interesting there. In advance, thanks for the reply.

### Received (2/2)

*\*No reply\**



## Appendix 7: Template for Scenario

Scenarios	<i>Structure guide</i>	
<b>Story structure</b>		
Set the scene		
<hr/>		
<hr/>		
Introduce the character		
<hr/>		
<hr/>		
Problem/issue/need/motivation		
<hr/>		
<hr/>		
Discovery/resolution		
<hr/>		
<hr/>		
<b>Narrative</b>		
Short title:		
<hr/>		
<hr/>		
<hr/>		
<hr/>		
<hr/>		
<hr/>		
<hr/>		
<b>Key qualities</b>		
Make these visible in your concept		
1	2	3
<hr/>		
<hr/>		
184 Templates		

Figure 72. Appendix 7: Scenarios template (Tomitsch et al., 2018)



## Appendix 8: Instrument for usability testing

Notetaker

[name]

Participant #

[number]

Tested product

First low fidelity design of The Kahoot! League aimed at student-tasks.

How

The usability test will be held in-person and be a mix of moderated and unmoderated. The equipment that will be used are two laptops and one smartphone.

Introduction

We are a group of three student that are writing about our bachelor thesis. Our goal is to create a webtool that will increase the student engagement in a course. Our web tool is called “The Kahoot! League” and is used to display your Kahoot! Quiz results after completing a quiz.

Table 14. Appendix 8: Usability test template (Tomitsch et al., 2018)

<b>Tasks(s) (Enter a brief description for each task)</b>	<b>Success 0 = Not completed. 1 = Completed with difficulty or help. 2 = Easily completed.</b>	<b>Time to complete</b>	<b>Number of Errors</b>	<b>Notes/Observations (Note why the user was successful or not successful. E.g., wrong pathway, confusing page layout, navigation issues, terminology)</b>
<b>#1: You have been invited to use the new web tool “The Kahoot! League”. Your task is to log in with your username (Brian) and</b>				

<b>password starting from this screen.</b>				
<b>#2: You have participated in a Kahoot!-quiz in the IDG2100 lectures. The lecturer has uploaded the results and you want to know how many correct and incorrect answers you got in quiz 1 in IDG2100. Your task is to find how many correct and incorrect answers you got.</b>				
<b>#3: It is in the middle of the semester, and you have now completed multiple quizzes in the IDG2100 course. You want to know where you are on the leaderboard for IDG2100. (Brian).</b>				
<b>#4: You want to know more about the Kahoot! League. Your task is to find the About Page.</b>				

## Appendix 9: E-mail sent to students for usability testing

Hei, *[First name]*!

*Glenn, Cornelius og jeg jobber med bacheloroppgaven våres i vår. Vi er på det stadiet der vi skal utføre brukertester på vår low-fidelity-prototype. Ettersom du er i målgruppen til oppgaven våres, ønsker vi gjerne å invitere deg til å delta på vår brukertest. Vi er ledige følgende tidspunkt:*

- *09.02.22 13:00-17:00*
- *10.02.22 14:00-15:00*
- *11.02.22 10:00-17:00*

*Ved interesse, svar gjerne på denne e-posten og fortell oss når du er ledig slik at vi kan avtale tid og møtested med konkret.*

*Om du har noen andre spørsmål kan disse henvises til: [cornelos@stud.ntnu.no](mailto:cornelos@stud.ntnu.no), [glenneha@stud.ntnu.no](mailto:glenneha@stud.ntnu.no), [tomschr@stud.ntnu.no](mailto:tomschr@stud.ntnu.no)*

*Vennlig hilsen,*

*Cornelius, Glenn og Tom*

## Appendix 10: E-mail sent to administrators for usability tests

*Hello, [First name],*

*Our bachelor group is designing and developing a tool to engage students in their lectures for our bachelor thesis. We are currently in the testing phase and want to test our design on a lecturer/employee at NTNU.*

*We have created a Calendly-link you can schedule a meeting time that fits you.*

*Schedule your meeting here: [link to calendly]*

*Thank you in advance.*

*Best regards,*

*Bachelor group 2*

*Cornelius Ottar Sandmæl, Glenn Eirik Hansen, and Tom Schrie*

## Appendix 11: Database's various schema, fields and schemaTypes

Schema	Fields	SchemaType
<b>User</b>	username	String, unique, required, trim, lowercase
	email	String, trim, lowercase
	password	String, required
	role	String, required, enum: ['student', 'teacher', 'superAdmin'], default: 'student'
	programmeCode	String, trim, uppercase
	year	Number, trim
	courses	Array of String, trim
	studyProgrammes	Array of String, trim
<b>RefreshToken</b>	user	ObjectId, ref: 'User'
	token	String
	expires	Date
	created	Date, default: Date.now
	createdByIp	String
	revoked	Date
	revokedByIp	String
	replacedByIp	String
<b>studyProgramme</b>	studyProgrammeCode	String, unique, default: function () { const _t = this; const lastTwo = _t.year.toString().slice(-2); return _t.programmeCode + lastTwo; },
	name	String, required
	programmeCode	String, required
	year	Number, required
	startTerm	String, enum: ['fall', 'spring']
	studyPeriods	Array of objects
	studyPeriods.periodNumber	Number, trim, min, max
	studyPeriods.dates	Object

	studyPeriods.dates.term	String, enum: ['fall', 'spring'], default: function () { const _t = this; return _t.startTerm === 'fall' ? _t.periodNumber % 2 == 0 ? 'spring' : 'fall' : _t.periodNumber % 2 == 0 ? 'fall' : 'spring'; },
	studyPeriods.dates.startDate	String, default: function () { const _t = this; return _t.dates.term === 'fall' ? 'August' : 'Januar'; },
	studyPeriods.dates.endDate	String, default: function () { const _t = this; return _t.dates.term === 'fall' ? 'December' : 'Juni'; },
	studyPeriods.code	String
	studyPeriods.name	String
	studyPeriods.startTerm	String, enum: ['fall', 'spring']
	studyPeriods.courses	ObjectId, ref: 'Course'
	users	ObjectId, ref: 'User'
<b>Course</b>	code	String, required
	courseId	String, required
	Name	String, required
	credits	Number, required
	activities	Array of objects
	Object.name	String, required, default: 'quiz', trim, lowercase
	Object.variant	String, required, default: 'kahoot', lowercase, trim
	Object.sources	ObjectId, ref: 'Kahoot'
<b>Kahoot</b>	partOfCourse	ObjectId, ref: 'Course'
	course	Object

Course.courseId	String
Course.code	String
Course.name	String
quizId	String, trim, lowercase, unique, default: function () { const _t = this; const date = new Date(_t.playedOn); const day = date.getDate(); const month = date.getMonth(); return `\${_t.title}-\${day}- \${month}`; },
title	String, required
playedOn	Date, required
hostedBy	String, required
numberOfPlayers	String, required
finalScores	Array of objects
Object.rank	Number
Object.player	String, trim, lowercase
Object.totalScore	Number
Object.correctAnswers	Number
Object.incorrectAnswers	Number

# Appendix 12: JSON data extracted from the web development study program

JSON snippet extracted from the Web Development study program at NTNU. See

[https://www.ntnu.no/web/webutvikling-bwu-/studiets-oppbygging?p\\_p\\_id=studyprogrammepartnerportlet\\_WAR\\_studyprogrammepartnerportlet\\_I\\_NSTANCE\\_uMhlebfzfuY6g&p\\_p\\_lifecycle=2&p\\_p\\_state=normal&p\\_p\\_mode=view&p\\_p\\_resource\\_id=studyplan&p\\_p\\_cacheability=cacheLevelPage&code=BWU&year=2019](https://www.ntnu.no/web/webutvikling-bwu-/studiets-oppbygging?p_p_id=studyprogrammepartnerportlet_WAR_studyprogrammepartnerportlet_I_NSTANCE_uMhlebfzfuY6g&p_p_lifecycle=2&p_p_state=normal&p_p_mode=view&p_p_resource_id=studyplan&p_p_cacheability=cacheLevelPage&code=BWU&year=2019) for JSON

```
{
  "settings": {
    "programmeCode": "BWU",
    "year": "2019"
  },
  "studyplan": {
    "code": "BWU",
    "name": "Bachelor i webutvikling",
    "year": "2019",
    "startform": "HØST",
    "updated": "04-03-2022 at 04:31:04",
    "studyPeriods": [
      {
        "periodNumber": "1",
        "direction": {
          "code": null,
          "name": null,
          "studyDirectionDesignationCode": null,
          "studyDirectionDesignationName": null,
          "studyWaypoints": [],
          "courseGroups": [
            {
              "code": "BWU1-19",
              "name": "1.år - Bachelor i webutvikling",
              "description": "Emne i 1.studieår",
              "deadlineDate": null,
              "relperiod": 1,
              "courses": [
                {
                  "code": "IDG1362",
                  "version": "1",
                  "name": "Designenkning",
                  "credit": "7.5",
                  "planelement": false,
                  "studyChoice": {
                    "code": "0",
                    "name": "Obligatorisk emne",
                    "description": "Obligatorisk emne"
                  }
                },
                {
                  "code": "TDG1000",
                  "version": "1",
                  "name": "Grafiske verktøy, prinsipper og metoder",
                  "credit": "7.5",
                  "planelement": false,
                  "studyChoice": {
                    "code": "0",
                    "name": "Obligatorisk emne",
                    "description": "Obligatorisk emne"
                  }
                },
                {
                  "code": "TDG1100",
                  "version": "1",
                  "name": "Grunneme webutvikling",
                  "credit": "7.5",
                  "planelement": false,
                  "studyChoice": {
                    "code": "0",
                    "name": "Obligatorisk emne",
                    "description": "Obligatorisk emne"
                  }
                },
                {
                  "code": "IDG1292",
                  "version": "1",
                  "name": "Webkoding",
                  "credit": "7.5",
                  "planelement": false,
                  "studyChoice": {
                    "code": "0",
                    "name": "Obligatorisk emne",
                    "description": "Obligatorisk emne"
                  }
                }
              ]
            }
          ]
        }
      }
    ]
  }
}
```



## Appendix 13: Results from usability test #1 with students

Table 15. Appendix 13: Results from usability test #1 with students

Low fidelity 1 – Student					
Participant	Task	Success	Time	Errors	Notes
#1	#1		2 13:57s	0	As expected
	#2		2 11:36s	0	As expected
	#3	2	29:19s	1	Goes back instead of clicking burger menu
	#4		2 06:25s	0	As expected
#2	#1		2 09:60s	0	As expected
	#2		2 08:13s	0	As expected
	#3		2 07:07s	0	As expected
	#4		2 04:13s	0	As expected
#3	#1		2 22:00s	0	As expected
	#2		2 06:32s	0	As expected
	#3	1	16:20s	2	First my Results, then My Profile, then the burger menu and leaderboard
	#4		2 05:36s	0	As expected
#4	#1		2 06:33s	0	As expected
	#2		2 13:69s	0	As expected
	#3		2 09:92s	0	As expected
	#4		2 04:45s	0	As expected
#5	#1		2 17:05s	0	As expected
	#2		2 19:90s	0	As expected
	#3	1	25:59s	1	Goes back instead of clicking burger menu
	#4		2 06:46s	0	As expected

## Appendix 14: Results from usability test #2 for students

Table 16. Appendix 14: Results from usability test #2 for students

Low fidelity 2 – Student					
Participant	Task	Success	Time	Errors	Notes
#1	#1		2 29:06s	0	As expected
	#2		2 51:63s	0	As expected
	#3		2 18:35s	0	As expected
	#4		2 18:74s	1	Navigates to home first
#2	#1		2 07:04s	0	As expected
	#2		2 10:55s	0	As expected
	#3		2 21:51s	0	As expected
	#4		2 03:28s	0	As expected
#3	#1		2 11:92s	0	As expected
	#2		2 15:60s	0	As expected, might be some information overload
	#3		2 14:04s	0	As expected
	#4		2 08:88s	1	Goes back to My Results before about, add text under icons in navbar
#4	#1		2 09:00s	0	As expected
	#2		2 19:95s	0	As expected, can't see which questions they got wrong
	#3		2 09:45s	0	As expected
	#4		2 05:83s	0	As expected
#5	#1		2 08:21s	0	As expected
	#2		2 26:07s	0	As expected
	#3		2 06:36s	0	As expected
	#4		2 10:73s	0	As expected
#6	#1		2 21:52s	0	As expected, small font
	#2		2 20:73s	0	As expected
	#3		2 04:37s	0	As expected
	#4		2 06:19s	0	As expected

## Appendix 15: Results from usability testing #1 for administrators

Table 17. Appendix 15: Results from usability testing #1 for administrators

Low fidelity 1 – Admin					
Participant	Task	Success	Time	Errors	Notes
#1	#1		2 22:19s	0	As expected
	#2		1 80:45s	3	Navbar doesn't make sense
	#3		1 46:32s	2	Initially looks for it in leaderboard
	#4		2 27:12s	1	Navigates to about first, then back to admin
	#5		2 27:61s	1	Navigates to about before leaderboard
#2	#1		2 09:09s	0	As expected
	#2		1 31:83s	1	Navigates to leaderboard before admin-page
	#3		2 19:30s	1	Struggles to find manage quizzes
	#4		2 13:43s	0	As expected
	#5		2 03:43s	0	As expected
#3	#1		2 08:24s	0	As expected
	#2		1 53:03s	2	Navigates to leaderboard before admin-page
	#3		1 22:87s	1	Struggles to find manage quizzes
	#4		1 33:11s	1	Struggles to find invite user
	#5		1 03:98s	1	Struggles to find correct leaderboard
#4	#1		2 06:82s	0	As expected
	#2		1 35:12s	1	Navigates to leaderboard before admin-page
	#3		2 25:04s	0	As expected, wants a confirmation message when deleting
	#4		1 38:00s	4	Navigates to about, then settings, then leaderboard, then correct
	#5		2 06:34s	0	As expected
#5	#1		2 07:86s	0	As expected
	#2		1 213:77s	6	Really struggles to find admin-page
	#3		2 27:12s	0	As expected, wants an undo button
	#4		1 122:94s	3	Struggles to find invite user button
	#5		2 09:89s	0	As expected

## Appendix 16: Results from usability testing #2 for administrators

Table 18. Appendix 16: Results from usability testing #2 for administrators

Low fidelity 2 – Admin					
Participant	Task	Success	Time	Errors	Notes
#1	#1		2 02:34s	0	As expected
	#2		2 07:54s	0	As expected
	#3		2 07:61s	0	As expected
	#4		2 10:33s	0	As expected
	#5		2 03:06s	0	As expected
#2	#1		2 06:93s	0	As expected
	#2		2 24:53s	1	Navigates to Settings first, then leaderboard, fullstack and upload
	#3		2 16:76s	0	As expected
	#4		2 17:98s	0	As expected
	#5		2 06:29s	0	As expected
#3	#1		2 48:52s	0	As expected
	#2		2 41:31s	0	As expected
	#3		1 67:86s	3	Navigates to leaderboard and course, then settings before manage-page
	#4		2 50:62s	1	Navigates to leaderboard then back to admin-page
	#5		2 04:47s	0	As expected
#4	#1		2 12:89s	0	As expected
	#2		2 46:09s	0	As expected, wants some text underneath the FAB
	#3		2 37:43s	0	As expected
	#4		2 35:37s	0	As expected, the name dashboard doesn't make sense
	#5		2 12:19s	0	As expected, would like some more stats about each user. E.g., amount of quizzes the user has partic

