

# Designing a social component for MathsCamp

Mia Valentin Valdbjørn Rønnelund

Master of Software Design  
IT University of Copenhagen

*miro@itu.dk*

**Supervisor:**

Mircea Lungu

*mlun@itu.dk*

**Project code:**

KISPECI1SE

1 June 2022

**Abstract**

Our human nature is making us compare ourselves to everyone around us at all times, especially in an educational setting, where we are always met with a ranking of our progress, and we are always comparing our skills with our friends. The act of social comparison is closely related to competition, as our competitive behavior stems from our tendency to compare ourselves with others. A leaderboard is a competitive element, which is nourishing this social comparison. When creating a leaderboard in an education setting, it is important that it creates more positive than negative results.

This thesis is researching how to design a leaderboard in a way that it is motivating the students to learn, rather than discouraging and deflating them. This thesis is designing, implementing, and evaluating such leaderboard into the existing web app called MathsCamp. The results show that the design of the leaderboard is generally motivating to the students, even for those who are in the bottom positions.

# Contents

<b>1</b>	<b>Introduction</b>	<b>1</b>
<b>2</b>	<b>Related work</b>	<b>2</b>
2.1	Previously conducted research . . . . .	2
2.2	Existing apps . . . . .	4
<b>3</b>	<b>Solution</b>	<b>5</b>
3.1	High-fidelity prototype . . . . .	6
3.2	Software architecture . . . . .	9
3.2.1	Refactoring . . . . .	9
3.2.2	Database design . . . . .	11
3.2.3	Source code . . . . .	13
<b>4</b>	<b>Evaluation</b>	<b>16</b>
4.1	Database observations . . . . .	16
4.2	Hotjar . . . . .	17
4.3	Questionnaire . . . . .	19
<b>5</b>	<b>Discussion</b>	<b>22</b>
5.1	Limitations . . . . .	23
5.2	Future work . . . . .	24
<b>6</b>	<b>Conclusion</b>	<b>24</b>

# 1 Introduction

Designing competition for children can be challenging, in particular designing it in such a way which are motivating, rather than discouraging and making the children feel outcasted.

MathsCamp is an educational web app created by Schjødt-Pedersen and Therkildsen[1], which this thesis will be building on top of. MathsCamp was created in order of making an educational tool that could encourage the students in the age 12-13 to learn mathematics in an encouraging and playful way, by implementing gamification in the learning activity.

When designing for children, there are multiple considerations to take into account. Designing for Children's Rights (D4CR) is an organization which has developed ten principles, which should be kept in mind when designing for children. The principles are created from the children's point of view and are created to enhance the protection of children's rights[2].

MathsCamp has already implemented some of these principles, such as creating a space for play and growth. However, there are still principles which are not yet met by MathsCamp. Principle 7 states "Encourage me to be active and play with others"[3], this principle are stating that the children's well-being, creativity, and self-expression are being enhanced when they share with others. MathsCamp is an individualized learning platform, they are not encouraging the students to share their growth with other students.

There exist multiple methods which can encourage social growth, such as encouraging the students to collaborate, or encouraging the students to share their own learning growth through competition. One such competition method is a leaderboard, which when implemented to MathsCamp will encourage the students to learn math by competition, for them to share their own growth or to beat their friends.

The aim of this thesis is to research, implement and evaluate the use of a leaderboard for the web app MathsCamp. This thesis aims to answer the following research question: *How can we design a leaderboard, which encourages the students to learn while ensuring that no students are feeling discouraged or excluded.*

This thesis consists of an exploration of previously conducted research and existing educational apps which are using a leaderboard. Additionally, this thesis includes the design, the design decisions behind the leaderboard, and the implementation of the leaderboard. Lastly, the leaderboard will be tested with the user group (students at the age of 12), and the results analyzed and evaluated.

## 2 Related work

This section elaborates on previous research regarding competition, motivation, and the effect of using a leaderboard. Additionally, the section will look into existing digital education apps such as Kattis, Duolingo, and Kahoot. These web apps are among the most used educational apps and are all using leaderboards to encourage their users to learn. These research and web apps are creating the baseline for the missing component of MathsCamp, and the foundation for the design of the leaderboard in MathsCamp.

### 2.1 Previously conducted research

Our human nature is making us always compare ourselves to everyone around us[4]. Especially in an education setting, we are always met with a ranking of our progress (in form of grades), and we are often comparing ourselves and our skills to our friends and fellow peers. Social comparison and competitiveness are connected, as competitive behavior often stems from the human nature of social comparison[5]. A leaderboard is a competitive element, which is nourishing the social comparison, and in such a competitive setting, it is important that the leaderboard opposes more positive than negative affect.

Landers et al.'s research[6] are presenting a brainstorming task to a group of people, in order of determining if and how a leaderboard enhances the performance of these people. The participants are divided into four different groups, which each are being given a specific goal, such as *do-your-best*, *easy*, *difficult* and *impossible*. The brainstorming task that the participants were given consisted of listing different uses of a knife. The *do-your-best* group were asked to find as many tags as possible, whereas the *easy* group were told to find 15 tags, the *difficult* group should find 39 tags and lastly the *impossible* group should find 52 tags. Additionally, a leaderboard group was created, where the people in the group were presented with a leaderboard and given points for each tag that they found in the brainstorming task. The leaderboard presented consisted of fictional users, this knowledge was not known to the participants. The results from the test showed that the leaderboard group performed significantly better than the *do-your-best* and *easy* group, meaning that they produces more tags in the brainstorming. Whereas, they produced similar number of tags as the *difficult* and *impossible* group. The conclusion from this research was that the participants in the leaderboard group were more encouraged to produce tags even without being given a specific goal. However, the

research from Landers et al. is not looking into the reasons that the leaderboard is performing better. Their results show that the participants presented with the leaderboard are performing better than those with small goals, but whether they do that because they want to be better, or whether it is because they are trying not to lose or look bad, or a third unknown reason is not presented in their research.

Implementing gamified elements into non-game situations is not new. A professor from MIT wrote a paper in 1981, concluding that children are in fact learning from playing video games[7]. In the following years, gamified elements have become more and more popular to implement into non-game situations, such as education. An important aspect when implementing such elements is to know whether it produces a positive outcome for the students (increase their motivation to learn, improve their grades, etc.).

Researchers such as Mekler et al.[8] or Barata et al.[9], has researched the effect of different gamification elements. Both their research are creating a situation where the students are met with gamified elements such as points, levels, badges, and a leaderboard. Mekler et al.'s initial research were examining whether these gamified elements harmed the intrinsic motivation among the students. The results from this research were that it does not harm the students' intrinsic motivation, but instead they found that the gamified elements showed an increase in the performance of the task they were presented with. Barata et al. research show similar results, that the gamified elements implemented were increasing the students' performances and attendance in the course where the elements were implemented. Both these research was performed on college or university students.

The research by Mekler et al. and Barata et al. are examining the leaderboard in relation to, or together with, other gamification elements, and not the leaderboard in isolation. Their research shows that gamification, in general, is increasing the students' performances, or that the leaderboard is performing better than other elements such as levels, points, or badges, but not whether the leaderboard itself produce the motivation, and therefore is a particular focus of this research.

Leaderboards exist in many different forms, they can contain all users or different groups of users. They can show absolute ranking, only the top users or the users' own position. Bai et al.[10] have done research in order of examining which type of leaderboard is the most beneficial in regards to the student's performance, course engagement, intrinsic motivation, and perception. Their research are examining two different types of leaderboards. *The absolute leaderboard*, which are displaying all

students from 1st to last place. The second leaderboard in their research is *the relative leaderboard*, which are showing the user's own position, and the relative five users.

The result showed both positive and negative sides to both leaderboards. The *absolute leaderboard* did not show any difference in the performances among the different positions on the leaderboard, but it did show that the student in the top positions was more intrinsically motivated. The *absolute leaderboard* additionally showed that the bottom positioned students suffered under the pressure of losing face and preferred an anonymous leaderboard. The *relative leaderboard* showed that the students in the top positions showed a higher performance than the students in other positions. Additionally, the *relative leaderboard* showed that the students at any positions were more likely to be content with their current position, and did not strive to be higher on the leaderboard.

The research by Bai et al. are only researching two types of leaderboards, and are not considering more options. Such as if the leaderboard were only showing the top positions, whether that would fix some of the issues with both leaderboards. If a top 10 leaderboard, would make the students in the bottom positions motivated to get higher on the leaderboard, and not just be content with the current positions, or whether the bottom positioned students won't suffer under the pressure of losing face as they are not being displayed to the other students.

## 2.2 Existing apps

As previously mentioned, the act of implementing gamified elements such as a leaderboard to non-game situations such as education has been around for several years. We see examples of leaderboards being used as motivational factors or displaying progress in other apps. This section will describe three educational apps and how they are using leaderboards. Looking into the top educational apps on the market, which are also including leaderboards, we see web apps such as Kattis, Kahoot, and Duolingo. Therefore, these three apps have been chosen to be examined in this section.

Assuming these apps have performed their research regarding the use of leaderboards, their benefits, and which type works for their app, we are able to use these apps as inspiration for how to design and implement leaderboards into MathsCamp.

**Kattis**[11] is an educational web app, which contains programming exercises the user can solve. When a user registers a Kattis account, they are able to say which country they are from, and which subdivision they are part of (e.g. choosing Denmark as your country, you can choose Capital region, central Jutland, etc.), your university, etc. Kattis thereby have a lot of leaderboards, as there

exists a leaderboard for every subgroup (country, subdivision, university, all users, etc.). Everyone is allowed to see all of these leaderboards, but as Kattis' community consists of millions of users, for larger groups such as universities, countries, etc. the leaderboard is only showing the top 50 users and not the absolute leaderboard. On the user's own page they are able to see their own ranking.

**Kahoot**[12] is a quiz-game web app. The quizzes are user-generated, and when starting a quiz, it contains a certain code that the users need to type in to participate. This means that the participants in the quiz only contain a limited number of people, such as a classroom or a group of friends. The leaderboard exists only for the duration of the quiz. When a quiz is running, the participants are able to see the top 5 positions and their own position after each question, and thereby also see whether their progress is increasing or decreasing in rank. When the quiz is finished, the top three participants are highlighted. Your own position, if not among the top users, is not visible to the other participants. You are able to go back to quizzes in which you have participated, and see the top three, but more information on previous results is not given. No leaderboard exists outside of the quiz.

**Duolingo**[13] is a language learning app. Duolingo allows you to follow friends, and you are able to see their achievements, but there is no direct comparison to yourself. Duolingo has a different kind of leaderboard than Kahoot and Kattis. There exist different ranks, and as a user, you are placed in the bottom rank, with a group of 30 randomly selected users. The top 10 of the users will progress to a higher rank when the week is over, the bottom 10 people will decrease in rank and the last people will stay in the same rank. Each week the leaderboard is reset. The only similarity among the 30 users is that they are learning the same language. The users are not placed in groups with their friends.

### 3 Solution

This section will present how the leaderboard for MathsCamp was designed and implemented. The section will include a presentation of the Figma prototype, in order of showing what the design should look like before the implementation. Additionally, this section will describe the system architecture, which includes a presentation of the refactoring of the existing code, the changes that were made to the database to accommodate the design choices for the leaderboard, and lastly a description of the



implementation.

The leaderboard created for this project are coded in React[14] and implemented into the existing MathsCamp. MathsCamp can be found at [mathscamp.org](https://mathscamp.org), or in the GitHub repository<sup>1</sup>. The repository contains all of the code for MathsCamp, including the leaderboard.

### 3.1 High-fidelity prototype

To visualize the design of the leaderboard, before implementing it, a prototype was created in Figma<sup>2</sup>. When designing the leaderboard, there were several considerations to be made. As a leaderboard implies a competition between the users, it also implies that there exists winners and losers. Being a winner is a great feeling, but being a loser can be deflating and demotivating. Peter et al.[15] are presenting three key elements which should be focused on when designing for motivation and well-being. The key element are:

- **Autonomy:** Acting on own willingness and choice
- **Competence:** The feeling of being capable and effective
- **Relatedness:** Feeling a connection to others.

Sometimes it is possible to satisfy all elements, but in a situation like a leaderboard, where one might find themselves not to be part of the "winners", can course the lack *competence* to satisfy their well-being. It is therefore important that the other elements are satisfied or that the leaderboard is designed in such a way that the users feel competent even if they are not in the top positions.

We as humans are always comparing ourselves to others, but especially when we are competing, we have a tendency to be more motivated by comparing ourselves to the people who are closest to us, or those with who we share most similarities with[4]. In education we share the most similarities with those within our own class, it is those with who we share the same age and skill level, and additionally also those who often become our friends. Additionally, research shows that extroverted people benefit more from leaderboards, compared to introverted people[16], but designing the leaderboard in a way such that it only contains people which whom the users are familiar with, will help the introverted users to feel less self-conscious, and thereby making the leaderboard more motivating for them.

Therefore, for the design of the leaderboard, we are creating classrooms, such that the students are only being compared to the students within their own class. Instead of the leaderboard consisting

---

<sup>1</sup><https://github.com/MathsCamp/MathsCamp>

<sup>2</sup><https://figma.fun/A1501A>

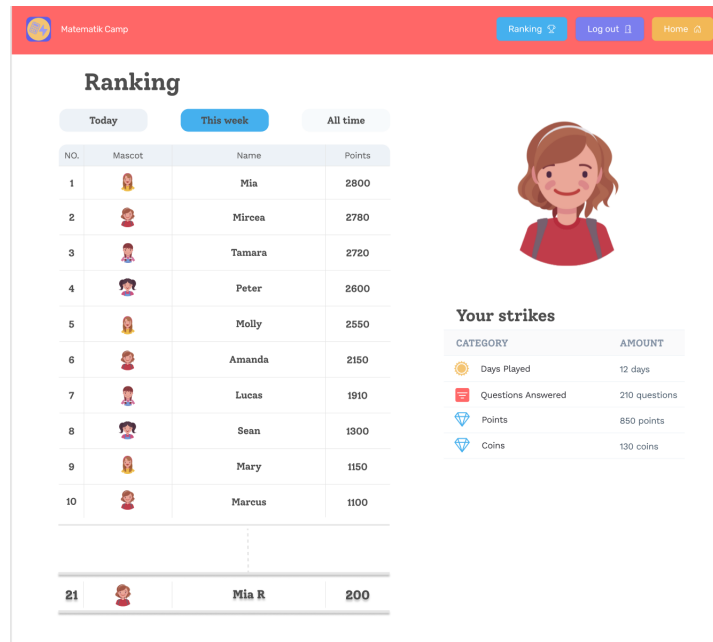


Figure 1: Leaderboard with user not in top 10

of students which the user might not know like Duolingo does, the leaderboard for MathsCamp are satisfying the relatedness element, as the students have a close relation to the other students in the leaderboard, like the leaderboard in Kahoot.

The results from Bai et al.'s research[10] showed that both the absolute and relative leaderboard, both had positive and negative effects. The leaderboard for MathsCamp will be designed such that only the top 10 users are being displayed, in order of trying to avoid the bottom positioned users feeling the pressure of losing face, but still motivating them to reach the top positioned and not just be content with their position. Figure 1 shows an example of the user not being part of the top 10, but they are still able to see their own position on the leaderboard. Additionally, the current user's name is highlighted to make their own position stand out.

As seen in figure 1, three different filtering buttons have been added. This makes it possible for the students to filter the leaderboard, so they can see a leaderboard for the *all time* scores, this *week* score, and *today's* score. The filtering is created with the idea that all students should have a chance to be in the top 10. The idea is that the points are being "reset" each week or day, for the students who are not on the leaderboard in the all-time filtering, and might not have been able to work that much on the math skill this week, they have the opportunity to revenge themselves the

week after, as the points in the week filtering will be reset.

Another design decision to be made is what type of measurement should be used to best showcase the user's success. The options for success measurement, based on the current solutions, are; points, number of mascots, or number of badges. As the learning tool that MathsCamp is, the score on the leaderboard should represent their skills within math. The score should boost the student's confidence and should make them feel successful.

The first measurement is points. In MathsCamp, the student is currently receiving 10 points for a correct answer, 5 points for a wrong answer, and 50 points for receiving a reward. Therefore, the points are a possible measurement for the student's success in not only answering correctly but also being involved and committed to the learning. The problem with points is that the students are able to buy mascots with these points. This means that the points are increasing and decreasing based on how they are buying new mascots. A student saving his/hers points will be seen as having higher success compared to a student having bought all available mascots. In order of using the points as measurement, there will need to be a change to how the point system works.

Another method of measuring success is the number of mascots that the students own. The students are able to buy mascots with their points. A mascot works as a profile picture to make MathsCamp more personalized. The number of mascots could be a representation of the user's success, as the current version of MathsCamp, the points are being used to buy the mascots. But mascots have different costs, and a student can save their points to buy a more expensive mascot. Therefore, a mascot with the price of 100 points is worth as much as a mascot with the price of 500, even though the mascot with 500 points requires more success on maths questions. Making all mascots the same price could make this type of measurement work for the leaderboard.

The number of badges could also be a possible success measure. The students receive a badge based on different accomplishments, such as how many questions they have answered, how many questions were correct, how many times they have looked at the explanation, the number of mascots and the number of days played. The rewards are not only showing the student's success in answering questions correctly but also in the student's commitment to learning (by having shown the explanation or played for multiple days). A disadvantage with badges and mascots is the possibility of filtering or resetting the leaderboard each week, for the students to see how well they are doing overall, this week or today, which are easier done with points.

Analyzing the positive and negative sides of each measurement type, the conclusion is to use

the points as measurement of success. The reason for this is that, despite having to change the point system, the point are showing the student's success in answering math questions correct, but they are also receiving points when earning a badge, and therefore the points is also an indication of their commitment to MathsCamp and to learn math. A solution to the point system used for buying mascots is to include coins in the user's information as well, which are then being used to buy mascots.

## 3.2 Software architecture

This section will describe how the leaderboard, with the design from the previous section, is implemented into the existing source code of MathsCamp. To streamline the existing code it was necessary to perform refactoring on parts of the code. Therefore, this section will firstly describe the refactoring process, which was necessary before the implementation. Thereafter, the section will present the changes made to the database to accommodate the design decisions. Lastly, the section will describe how the leaderboard has been implemented.

### 3.2.1 Refactoring

Receiving existing code might be difficult to navigate around, and in order of streamlining the code and start the implementation of the leaderboard, it was necessary to perform refactoring on the code.

Firstly, a few design changes were made, such as making the options in the practice section, all clickable, instead of it only being the radio button. Additionally, a few color saturation has been changed to enhance the contrast on different elements, and hover designs have been changed to make the web page feel more interactive.

Furthermore, it was not possible to take over the existing database, and therefore a new database needed to be created. The new database allows us to alter and add new tables. Because of the new database, it was necessary to change the API key and JavaScript key in `index.js` to establish a connection to the new database. With the new database, it also contains new `objectId`'s. An `objectId` is the primary key of an entity in a table, and these references to a specific entity. These `objectId`'s are used multiple times in the code, such as referencing to specific mascot or reward. In these cases where a specific `objectId` is being used, it needs to be changed to match the new `objectId` of the new database.

The file `multipleChoice.js`, which controls the practice section of MathsCamp, gathering the

questions from the database, updating points, etc., is generally a very long file, so a few changes to this file was made to make it more manageable. Firstly, global variables with the points and coins are created. Listing 1 shows an example where the student received a reward before refactoring. As there existed many cases in which the user receives points, global variables of the points were created to ensure accessibility.

```
1 const rewardPoints = originalpoints + 50;
2 student.set("total_points", rewardPoints);
```

Listing 1: Registering of points before the refactoring

Listing 2 shows the global variables, which are being used when registering points and coins for correct answer or receiving of reward. As seen the coins have been included in the variables. Additionally, the students are no longer receiving points for a wrong answer, and they are now receiving 25 points for a correct answer instead of the previous 10 points.

```
1 const correct_answer_point_reward = 25;
2 const correct_answer_coins_reward = 10;
3 const get_bagde_point_reward = 50;
4 const get_bagde_coins_reward = 25;
```

Listing 2: Global point variables

Another refactoring of `multipleChoice.js` was to extract a function to another file, in order of ensuring single responsible principle. When a student is answering correct on a question, there are different data which needs to be changed in the database, such as updating points and coins. Instead of having all this code be in `multipleChoice.js`, we call the new function and pass on the information that it needs (see listing 3). This refactoring are making `multipleChoice.js` more readable.

```
1 updatePointsOnCorrectAnswer(student, studentId, category, currentQuestionId,
   studentLevel, new_total_points, new_total_coins, categoryCompleteNotification);
```

Listing 3: Extracted function call

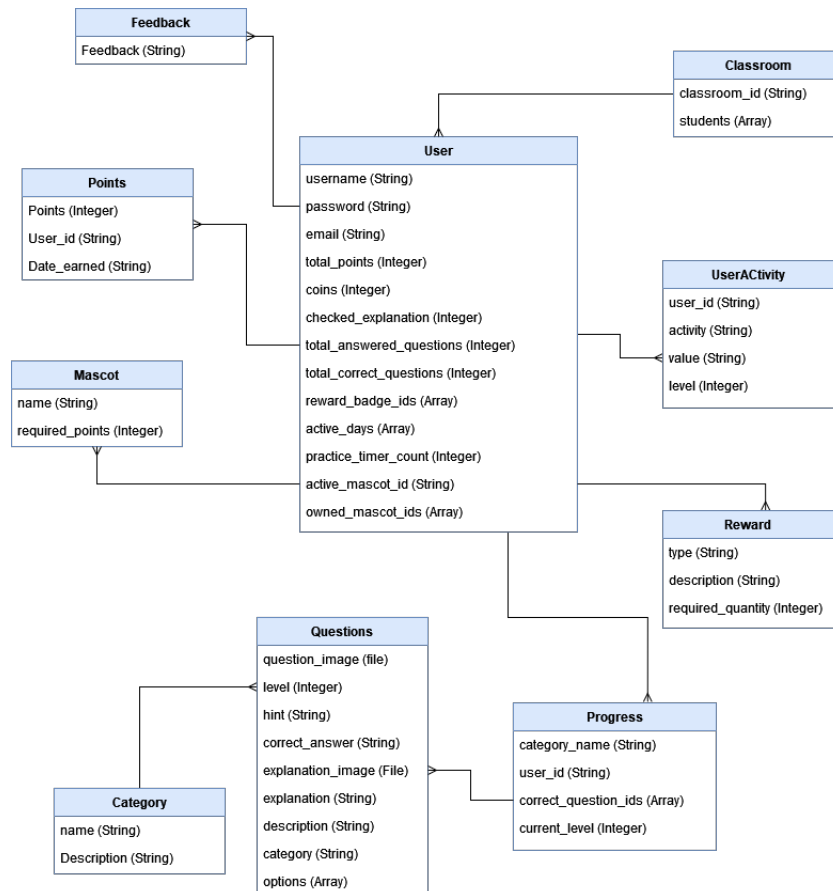


Figure 2: Relation diagram of Database

### 3.2.2 Database design

This project is using Back4app[17] as the service provider for the database. Figure 2 are showing the structure of the database and the relations.<sup>3</sup> Before implementing the design ideas into the source code, a few changes to the database should be performed. The changes include the change of the point system, as we in section 3.1 described how we are going to use the points as measurement. In order to do this, we need to change how points are stored. Additionally, classrooms are being added, such that the students are only being compared in the leaderboard with students of their own class.

<sup>3</sup>All tables in back4app are automatically created with the attributes: ObjectId, createdAt, updatedAt, and ACL. These are not written in the diagram.

### **New point system**

Two changes to the database need to be made, in regards to the point system. Firstly, the points should no longer be used to buy mascots. The solution to this is to create a new attribute called `coins` for the table `User`. The `User` table contains all the user's information (username, passwords, points etc.). Both points and coins are being earned when answering questions, but coins will be used to buy mascots, and points are being used as the overall score of how well the students are doing in regards to the math questions and earning rewards. As seen in Listing 2, with the new changes, the user is receiving 25 points and 10 coins for a correct answer to a question, and receive 50 points and 25 coins for winning a badge.

The design of the leaderboard includes filtering buttons, to filter the leaderboard into points earned *today*, *this week* and *all time*. With this filtering, another change to how the points are stored in the database needs to be made. The way the solution distinguish between points gained today, yesterday etc. is by adding a new class to the database called `Points`, containing the history of points earned. The attributes of this class are `User_id` which stores the id of the students who get points, `Points`, which stores the number of points the user gets, and `Date_earned` which stores the date of the point being given, in order to know when the student has received the point. Each time a user earns points (answering correctly or receiving a reward), a new entry to the database will be created with all the information needed. How the system is using this table to filter the points in the database will be described in section 3.2.3

### **Dividing students into classrooms**

When a student is registering a user at MathsCamp, they should additionally write a class code, which divides the students into the correct classrooms. The first consideration of the classroom code was to use the class entity's `objectId` as the distributed code, but due to security considerations of giving out the primary key of an entity in the database, the solution became to create an attribute to the table which consisted of the classroom code, which is manually created, and given to the teachers beforehand, and then they are distributing the code to their students.

In the database, a new table `Classroom` has been created. The table consist of two attributes `classroom_id` and `students`. A new entity is created manually in the database in order to create a new class. The `classroom_id` is a string, which is the code distributed to the class, and the code which should be typed in by the students when registering. When the students do this and register

a new user, their unique user id is saved to `students`, which is an array containing all the users who are registered in that class. In the leaderboard, the students will then only be compared to the students in that array, of which they are a part of.

### 3.2.3 Source code

The implementation of the leaderboard are developed using React, and GitHub was used for version control<sup>4</sup>. This repository contains all the code related to MathsCamp. This section will present the implementation of the leaderboard, including which new files were made and what alterations to existing files were made.

The leaderboard is presented to the user on a new page, this means that an additional page file should be added, this file is called `Ranking`. Routing to the new page is being added to `app.js`, and a button in the navigation bar, which navigates to the ranking page, is being added as well. The ranking file are rendering three components; A navigation bar, the ranking component (containing the leaderboard), and a footer.

As described in the design decisions in section 3.1, the decision became to use points as measurement of success in the leaderboard. This decision meant that we needed to change the buying of mascots, to use coins instead of points.

Additionally, regarding the points, section 3.2.2 describes a new way of registering points in the database was made. With this newly added table, we need to change the way in which points are being registered when the users are answering correct to a question or are receiving a reward. A new file called `submittingPoints.js` has been made. When the student has answered correctly, the function of the new file will be called, passing along the current student's id and the correct point variable. The function will then create a new entity in the database, registering the points.

The leaderboard itself is constructed using Table from the library `react.bootstrap`. Three additional files were created to control the collection of data from the database to create the leaderboard. `Ranking.js` gathers all the information needed in order to produce the leaderboard table. The leaderboard table should only contain the users within the same class as the current user. Using Parse SDK, it is possible to gather all the student which are part of the classroom. From each of the users in the classroom, the necessary information is gathered. The leaderboard is showing the name, the mascot, and the points from each of the students. All this information is saved in an array of objects (each object being a student).

---

<sup>4</sup><https://github.com/MathsCamp/MathsCamp>



With the new way of registering points in the database, each student might have multiple entities in the database table, and each of these should be counted to return the number of points that the user has. The second file, called `GetPoints.js` are performing the action of gathering and calculating the points. `Ranking.js` will call the function in `GetPoints.js`, passing along the student id and a filter. The filter corresponds to the filter which the student has chosen to see the leaderboard, such as today, this week, or all time. When counting points, `GetPoints` are taking the filter into account, and only calculates the total points based on this. As seen in listing 4, if the filtering is "today" the parse query will only find the cases in which `Date_earned` is equal to today's date (`today` is a variable containing today's date. `getWeek()` is a function which is finding all dates of this week, Monday - Sunday)

```
1 if (filter === "today") {
2     point_query.equalTo("Date_earned", today);
3 } else if (filter === "week") {
4     const this_week = getWeek();
5     point_query.greaterThanOrEqualTo("Date_earned", this_week[0]);
6     point_query.lessThanOrEqualTo("Date_earned", this_week[6]);
7 }
```

Listing 4: `GetPoints` checking filtering

Additionally, two files controlling the `leaderboardTable` component are created, which includes the js file and a corresponding css file, called `leaderboardTable`. In `Ranking.js` the bootstrap table is created with the headings for the different columns. For the body of the table, it sorts the array of the students by their points, and slice the array to only get the top 10 users. The `leaderboardTable` components is being used for each of these students, passing along the information that the leaderboard needs (see listing 5).

```
1 <Leaderboard
2     userid={student.userID}
3     rank={index + 1}
4     username={student.name}
5     current_mascot={student.mascotid}
6     total_points={student.points}
7 />
```

Listing 5: Leaderboard component

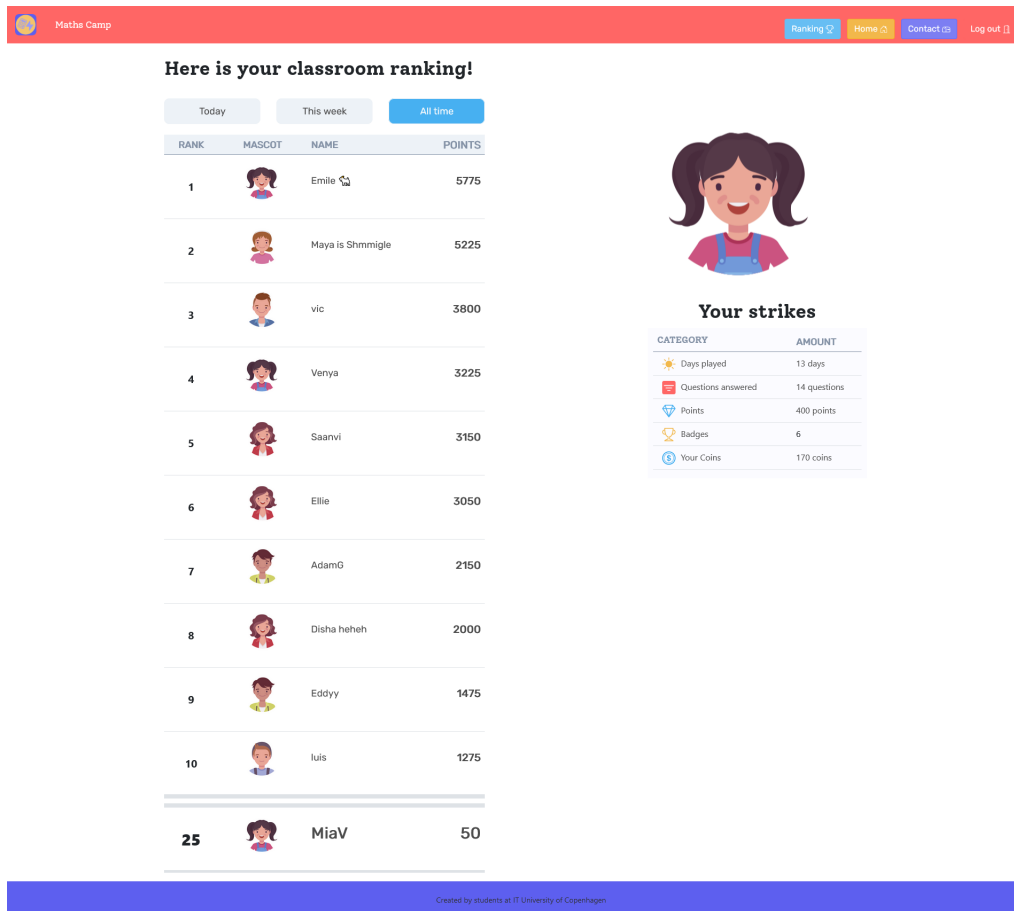


Figure 3: Leaderboard implemented in MathsCamp

The `leaderboardTable` are then creating each row of the leaderboard. It checks whether the user passed along is the current user, in that case, it should be using one type of styling, in order of highlighting the current user's own position on the leaderboard. If it is not the current user, another styling should be used. If the current user is not part of the top 10 users an additional row to the leaderboard is created after the leaderboard, showing the current users' position on the leaderboard.

The ranking page additionally shows the current users' other strikes. This is done by calling the `userInfoTable` components, which were part of the original code, and the same table shows in the sidebar on the front page. The final leaderboard, including the `userInfoTable` can be seen in figure

3

## 4 Evaluation

This section will analyze and evaluate the students' use, perception, and feedback of MathsCamp with the leaderboard. The evaluation is based on user testing sessions performed with three different classes, at two different schools. The first test was performed on 25 students in 6th. grade at Rygaards International School in Hellerup in Denmark, the test was performed physically, where I was able to help the students if any technical problems occurred. The other two tests were performed on a total of 34 students split across two classes at Halstead Preparatory School for Girls in Woking, United Kingdom, over zoom.

All three test sessions consisted of a presentation of MathsCamp, including how to register a user with the given classroom code (each class received their own classroom code), the features of MathsCamp, and how to navigate the website. Each test session lasted for one hour, and thereafter, the students were encouraged to use MathsCamp at home as well.

In order to evaluate the leaderboard, three different methods were used:

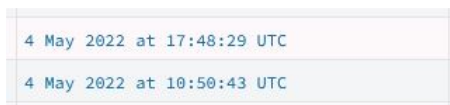
- Database observations.
- Hotjar implementation.
- Questionnaire for the students.

Each of these methods will be individually described and analyzed in the following sections.

### 4.1 Database observations

The first evaluation performed, was observing the data received in the database. The database includes a table called `UserActivity`, with the attributes `user_id`, which stores the current user's id and `activity` which registers the type of activity triggered. An entity is created with the current user's id and the activity `Ranking_clicked`, for each time a user click on the ranking button in the navigation menu.

The database has 77 registered users, but seeing that there were only 59 students participating in the test, I decided to look more into these registered users. It turns out that multiple students have created multiple users, but only played with one of the accounts. To better evaluate MathsCamp, I decided to refactor the 77 users of the database. This means that this evaluation is done



4 May 2022 at 17:48:29 UTC
4 May 2022 at 10:50:43 UTC

Figure 4: Example of two sessions on the same day, by the same user

on the users which have either answered maths questions or have visited the leaderboard. To determine whether they have been answering math questions, I looked at the users where the attribute *total\_answered\_questions*  $> 0$ , as this attribute registers the number of questions answered by the user, no matter if they answered wrong or correct. Additionally, I have included the users which have clicked on the ranking button in the menu bar. With these modifications, this evaluation ends up with 59 active users. Six of these users have answered math questions, but never checked the leaderboard, and one user has checked the leaderboard multiple times but never answered any math questions.

Looking into the `UserActivity` table, and calculating the number of click pr. user on the ranking button, and remember to include the 6 users which have zero clicks on the button, the average click pr. user is 4.45 clicks. The number of active days each student has had vary from 1-5 active days, but the average number of active days pr. student is 1.6 days. Calculating this into how many clicks pr. student pr. day, the results is  $4.45/1.6 = 2.27$  clicks pr. day.

The database are logging the date and time that each entry to `UserActivity` has been registered. Therefore, it is possible to check whether the students use MathsCamp multiple times a day, or just once pr. day. Figure 4 shows an example of a user who has been using MathsCamp both at 10:50 and 17:48 (24-hour clock), on the 4th of May, indicating that the user logged into MathsCamp two times that day.

The user presented in figure 4 is are rare example. It is most common for the users to only use MathsCamp once pr. day. This means that the 2.27 clicks per day also correspond to approximately 2 clicks per session in MathsCamp. Whether 2 clicks per session is a lot is hard to say, but what we can deduct from this is that the leaderboard is actually being used multiple times and that later in the evaluation, we know that the students' replies are based on their own experience.

## 4.2 Hotjar

Hotjar[18] is a tool which, when installed on a website, can track, record, and show the users' behavior. Hotjar is installed by writing a script to the `index.html` file. This script is provided by

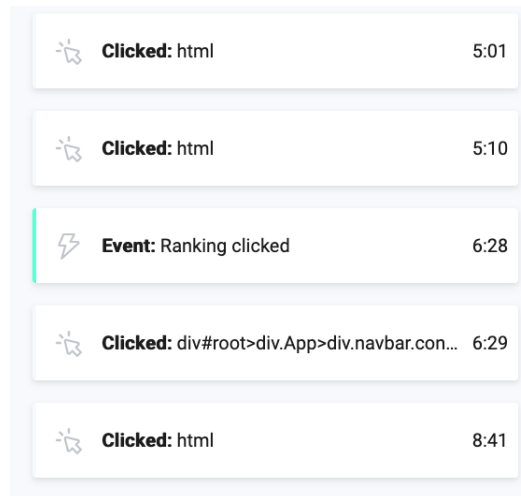


Figure 5: Example of Hotjar actions.

Hotjar and contains the Hotjar id, which is unique for the registration of a new workspace in Hotjar.

When the users are entering [mathscamp.org](https://mathscamp.org), Hotjar is starting to record their session. Hotjar will track their interaction with the website, such as where they click, their scrolling, or possible rage clicks. Additionally, it is possible to create *events*. Events are special triggers which are being used to highlight a specific interaction in the recordings of the users' session. In figure 5, we see an example of some of the list of actions which Hotjar is registering of a user. We see how an event called "Ranking clicked" has been activated. The event "Ranking clicked" is registered in Hotjar every time the user navigates to the ranking page.

When a session in Hotjar has been recorded, Hotjar determines its relevance, meaning that they make an assessment of how insightful the recording is based on the users' activities (e.g. number of clicks, events, duration, number of different pages visited, etc). 91 recordings of an average duration of 20 minutes have been registered. In order to evaluate the use of the leaderboard, it has been determined to only look at the recordings with high or very high relevance.

In the recordings, we are able to see the mouse movement and scrolling on the different pages, which is what will be used to analyze the users' interaction with the screen. In a recording that is 1 hour long, it can be difficult to know where the important actions happen, in regard to the leaderboard. This is where the event "ranking clicked" is important, as it makes it possible to only see the part of the recordings where the users are using the leaderboard, and their actions surrounding it.

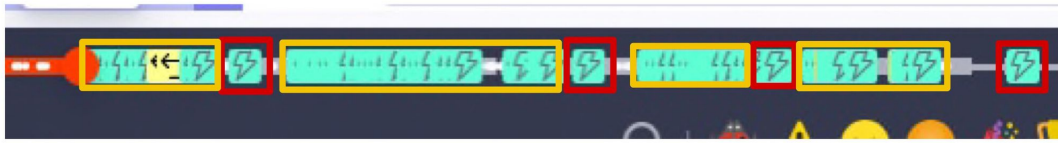


Figure 6: Action pattern in Hotjar

When a user is entering the ranking page, they seem to be scrolling until they find their own name on the leaderboard. For the users in the top 4, which are the users who are visible without any scrolling needed, are not scrolling further down the leaderboard. The users further down the leaderboard or not at the leaderboard at all, seem to scroll down the page until they reach their own name. Again this indicates that the users are more interested in their own position rather than others.

Another event called "new question" was created. This event is triggered when the user is met with a new question in the practice section (either entering the practicing section or pressing submit to a question). In the recordings of Hotjar, we were able to see a pattern of how the students are answering questions and checking themselves on the leaderboard. Figure 6 shows an example of a student who answered a series of questions (the yellow marking), thereafter checking the leaderboard (the red marking), and continuing this pattern 4 times. This pattern indicates that the students are trying to answer more math questions in order to see their position changing on the leaderboard, most likely hoping they have climbed the leaderboard.

### 4.3 Questionnaire

To get the students' feedback on their experiences with MathsCamp and the leaderboard, an online questionnaire was created. After the one week of allowing the students to play around with MathsCamp at home, the questionnaire was sent to the teacher, who was then sending the link to the students for them to answer. Appendix A are showing the questions from the questionnaire, and appendix B are showing the responses from the users.

22 students answered the questionnaire, these consisted of 8 males (36.4%), 12 females (54.5%), and 2 users (9.1%) which have answered "prefer not to answer". As seen in figure 7 all respondents were natural or satisfied with the overall experience with MathsCamp, no one answered that they were unsatisfied with the design of MathsCamp.

Looking into their perception of their use of the leaderboard, we see that 20 respondents (90.1%)



Figure 7: Overall satisfaction of MathsCamp

are saying that they have used the leaderboard when they were using MathsCamp, whereas 2 respondents (9.1%) chose that they haven't used it. The database observation in section 4.1, showed that 6 users are not using the leaderboard, as 59 students participated in the testing, and 22 users answered the questionnaire, we can assume that the remaining 4 users who have not used the leaderboard, are users which have not answered the questionnaire. Doing the presentation of MathsCamp to the children, they were made aware of the existence of the leaderboard, so them not being aware of it being there, can be excluded from the reason behind them not using the leaderboard.

Unfortunately, the questionnaire does not include a question that could allow these two students to elaborate on their reason for not using the leaderboard. Looking into what these two students have answered in the other questions we find that one of the students is generally positive, saying the leaderboard would make her feel excited and no matter whether she's in 1st place or not at the leaderboard, she is motivated to answer questions, so the reason for not using the leaderboard seems odd, as she seems to like the idea of it being there. The other students, on the contrary, answered that she would feel better than others being in 1st place, and feel like she is bad at math for not being on the leaderboard, and these reasons might be the reasons for her not using the leaderboard at all.

The questionnaire shows that the users are primarily using the leaderboard to check their own position (68.2%) or to compare themselves to their fellow students (59.1%). Additionally, the leaderboard creates a general positive feeling in the students, 40.9% says that the leaderboard makes them feel motivated, 18.2% says it makes them happy and 13.6% says it makes them feel smart. To further

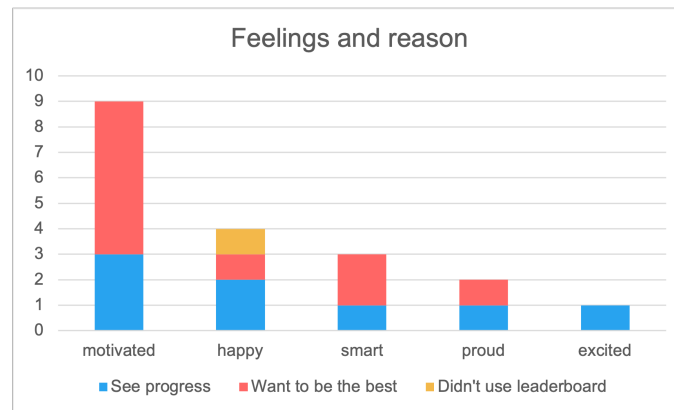


Figure 8: Students feelings towards the leaderboard and their reason behind

elaborate on these feelings, the students were asked why the leaderboard made them feel this way.

50% says it is because they want to be the best and beat their friends, whereas 40% says it was because the leaderboard made it possible for them to see their progress and improvement in math. Cross comparing how the students feel towards the leaderboard and why they are feeling that way. The results show that 67% feel motivated because they want to be the best. Additionally, the results of the questionnaire show that 50% of those feeling happy when seeing the leaderboard, is because they can see their progress (see figure 8)

As the leaderboard only shows the top 10 users, the students can be in two situations; being on the leaderboard or not being on the leaderboard. As the design of the leaderboard is designed to make the students motivated, but still make sure that the students won't feel discouraged, bad at math, or demotivated, the questionnaire contained questions asking them about how they feel being in 1st place or how they feel not being on the leaderboard at all. According to the questionnaire, when the students were asked what feeling they had if they were to be in 1st place, the most used words were motivated (31.8%), Excited (22.7%), and happy (18.2%). Additionally, the students were asked how they feel if they are not present on the leaderboard, meaning that they are not within the top 10 players. A small portion of the students answered that it makes them sad (18.2%), and other students used words as, unmotivated (2 students) or jealous (1 student), but a large portion (54.5%) answered that they feel motivated to answer more math questions in order to get on the leaderboard.



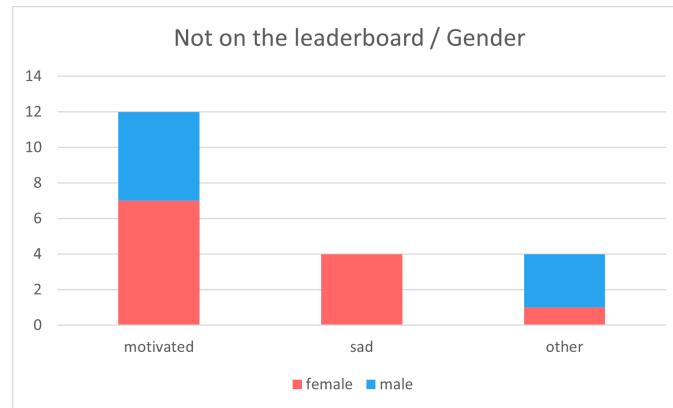


Figure 9: Students feelings when not on leaderboard, based on gender

If we cross-compare the feelings of not being on the leaderboard with the gender of the respondent (see figure 9), we see that those who are feeling sad about not being present on the leaderboard are the female respondents, whereas there is a larger part of male respondents which have chosen other words, such as jealous and competitive. Those who answered that they feel motivated, consist both of male and female respondents, without a major difference.

## 5 Discussion

The goal of the leaderboard was for the students to feel included and motivated, and avoid having the students feel demotivated or excluded if not in the top positions on the leaderboard. Gerber et al.[19], describes how we as humans have a tendency of comparing ourselves to those who are better than ourselves (upward comparison) rather than comparing ourselves to those inferior than ourselves (downward comparison). Looking at the recordings in Hotjar, of how the students are not scrolling down further than their own name, and the fact that they, themselves, are saying that they are comparing themselves to the other students, indicates that the students are in fact only comparing themselves with those students which are above them on the leaderboard, they are not scrolling down to see who else is on the leaderboard.

The overall conclusion based on the evaluation is that the students are generally feeling motivated by the leaderboard. Whether they are doing well or are working their way towards getting in the top 10 of the leaderboard. Designing the leaderboard in such a way which is not displaying all users seems to have a generally positive effect on the students based on other research and own

evaluation. The results are indicating that by not displaying the bottom students, not allowing them to be judged by their positions, are having a motivating effect. Whereas the top positioned students are still feeling the satisfaction of winning.

We do not know how the students are comparing themselves to the other students. As most students are feeling motivated by the leaderboard because they want to be the best, it suggests that the students are rather comparing themselves to the other student's points, rather than comparing themselves to the individual in the places above themselves. Which could be the reason why the students don't find the leaderboard social, as they are not looking at their friends, but rather at themselves and their progress.

The result of this thesis does however show a small fraction of students who are feeling sad or demotivated by not being on the leaderboard. The reason for these people feeling sad was not discovered during this research, but looking at other research such as Murayama and Elliot[20] or Ganai and Ledbetter [21], the participant's goal when competing has a large impact on whether they are feeling motivated or not. Murayama and Elliot's research shows that those whose goal is to win tend to benefit more from the competition that a leaderboard presents, whereas, for those whose goal is to not lose, competition seems to have a negative effect. In the evaluation, we see that most of those who are feeling motivated by the leaderboard, are feeling motivated because they want to win, which complies with the research from Murayama and Elliot. Those who are feeling sad for not being in the top 10 on the leaderboard, might have a goal of wanting to avoid losing, but without further exploration into the students' goals, we are not able to conclude this with certainty.

Ganai and ledbetter are talking about the reason behind participating, these *why's* comes from the design itself and not from the students' own perception. If the design is saying "you should play because you can win", the users who are not motivated by such reasoning, are once again being demotivated, as this is not their own goal for participating, rather the design should say "You should play because you can get better at math", might be more motivating for these students. The message which the students think the leaderboard communicates has not been explored, and we can not by any certainty say whether this is the reason for some of the students to feel demotivated.

## 5.1 Limitations

During the evaluation of this research, it was discovered that the filtering buttons did not work as intended. The filtering required the leaderboard to be fully loaded before a new filtering button is pressed. This means that if the user pressed the buttons before the leaderboard were fully loaded, the

leaderboard would contain points from the previous filtering, and thereby not show the complete picture of the correct filter. The solution to this would be to freeze the page until all data was successfully loaded, but as this was discovered late in the process, it was not possible to implement for the testing with the users, and it is therefore not possible to conclude on the functionality of the filtering buttons.

## 5.2 Future work

### Performance evaluation

This thesis is researching the children's own perception, regarding whether they think and feel that the leaderboard is motivating them to answer questions. But it is not looking into whether the leaderboard is enhancing their performance, or whether their skills within mathematics are increasing or decreasing.

### Cheating

This thesis does not take cheating into account, and it could be relevant to look into whether the users are cheating in order of reaching the top positions. Whether the users are motivated to reach the top positions, in such a way that they are cheating their way to it, rather than wanting to learn math to reach the top positions, and how that affects the cheating users' perception, as well as the non-cheating users' perception, of the leaderboard and MathsCamp.

### Leaderboard message

The message which the students think the leaderboard communicates has not been explored, and we can not by any certainty say whether this is the reason for some of the students to feel demotivated. Additional questions regarding the children's perception of the message which the leaderboard is communicating, and the students' goals, would help determine whether the leaderboard is communicating a message which is demotivating for the students.

## 6 Conclusion

This thesis is examining how to design a leaderboard for the web app MathsCamp, in such a way which is motivating and encouraging, rather than demotivating and deflating. Competition implies that there exist winners and losers, and when implementing a leaderboard, it is important to ensure

that those who are not among the winners are not feeling demotivated, but rather that they are feeling motivated to try their best and become one of the winners.

There exist different ways of implementing a leaderboard, such as an absolute or a relative leaderboard. This thesis is implementing the parts that worked well from both of these. The leaderboard for MathsCamp is designed such that it only contains the users within the students' own classroom, to ensure that the students are feeling a relation to the other students in the leaderboard. Additionally, the leaderboard is only showing the top 10 students. The research shows that the top users are feeling motivated to keep their position and that the majority of the users not among the top 10 are encouraged to work harder to reach the top 10 positions. By only showing the top positions, we are avoiding some of the problems an absolute leaderboard or a relative leaderboard opposes.

This thesis does however also show a minor group of users who are feeling sad for not being among the top 10 users. A concrete conclusion to the reason why these are feeling sad is not discovered during the research. However, based on previous research, we are able to assume that these users are either having a goal for competing, such as wanting to avoid losing, which is affecting them negatively, or that the leaderboard itself is communicating a message encouraging the students to participate on wrong foundations.

With this thesis, we are seeing that a leaderboard only displaying the top 10 users is motivating to the students in the age 12 to 13. Even the students not among the top positions are feeling motivated to pursue the goal of reaching a top-ranking position, and are not feeling discouraged.

## References

- [1] A. Schjødt-Pedersen and F. D. Therkildsen, “Designing a personalized learning app for math courses in elementary school,” IT University of Copenhagen, Tech. Rep., 2022.
- [2] Unicef Innocenti, *Researchers and designers convene to create ‘designing for children’ guide*, Jan. 2018. [Online]. Available: <https://www.unicef-irc.org/article/1746-researchers-and-designers-convene-to-create-designing-for-children-guide.html>.
- [3] D4CR, *Designing for childrens rights principles*, 2018. [Online]. Available: <https://childrensdesignguide.org/>.
- [4] S. M. Garcia, A. Tor, and T. M. Schiff, “The Psychology of Competition: A Social Comparison Perspective,” *Perspectives on Psychological Science*, vol. 8, no. 6, pp. 634–650, Nov. 2013, ISSN: 17456916. DOI: 10.1177/1745691613504114.
- [5] L. Festinger, “A Theory of Social Comparison Processes,” *Human Relations*, vol. 7, no. 2, pp. 117–140, 1954. DOI: 10.1177/001872675400700202. [Online]. Available: <https://doi.org/10.1177/001872675400700202>.
- [6] R. N. Landers, K. N. Bauer, and R. C. Callan, “Gamification of task performance with leaderboards: A goal setting experiment,” *Computers in Human Behavior*, vol. 71, pp. 508–515, Jun. 2017, ISSN: 07475632. DOI: 10.1016/j.chb.2015.08.008.
- [7] T. Malone, “What Makes Things Fun to Learn? A Study of Intrinsically Motivating Computer Games,” *Pipeline*, vol. 6, May 1981.
- [8] E. D. Mekler, F. Brühlmann, K. Opwis, and A. N. Tuch, “Do points, levels and leaderboards harm intrinsic motivation? An empirical analysis of common gamification elements,” in *ACM International Conference Proceeding Series*, Association for Computing Machinery, 2013, pp. 66–73, ISBN: 9781450328159. DOI: 10.1145/2583008.2583017.
- [9] G. Barata, S. Gama, J. Jorge, and D. Goncalves, “Engaging engineering students with gamification,” in *2013 5th International Conference on Games and Virtual Worlds for Serious Applications, VS-GAMES 2013*, 2013, ISBN: 9781479909650. DOI: 10.1109/VS-GAMES.2013.6624228.

- [10] S. Bai, K. F. Hew, M. Sailer, and C. Jia, “From top to bottom: How positions on different types of leaderboard may affect fully online student learning performance, intrinsic motivation, and course engagement,” *Computers and Education*, vol. 173, Nov. 2021, ISSN: 03601315. DOI: 10.1016/j.compedu.2021.104297.
- [11] Kattis, *Kattis*. [Online]. Available: <https://open.kattis.com/>.
- [12] Kahoot, *Kahoot*. [Online]. Available: <https://kahoot.com/>.
- [13] Duolingo, *Duolingo*. [Online]. Available: <https://www.duolingo.com/>.
- [14] Meta Platforms Inc, *React*. [Online]. Available: <https://reactjs.org/>.
- [15] D. Peters, R. A. Calvo, and R. M. Ryan, “Designing for motivation, engagement and wellbeing in digital experience,” *Frontiers in Psychology*, vol. 9, no. MAY, May 2018, ISSN: 16641078. DOI: 10.3389/fpsyg.2018.00797.
- [16] Y. Jia, B. Xu, Y. Karanam, and S. Voidsa, “Personality-targeted Gamification: A Survey Study on Personality Traits and Motivational Affordances,” in *Conference on Human Factors in Computing Systems - Proceedings*, Association for Computing Machinery, May 2016, pp. 2001–2013, ISBN: 9781450333627. DOI: 10.1145/2858036.2858515.
- [17] Back4App, *Back4App*. [Online]. Available: <https://www.back4app.com/>.
- [18] Hotjar Ltd, *Hotjar*. [Online]. Available: <https://www.hotjar.com/>.
- [19] J. P. Gerber, L. Wheeler, and J. Suls, “A social comparison theory meta-analysis 60+ years on,” *Psychological Bulletin*, vol. 144, no. 2, pp. 177–197, Feb. 2018, ISSN: 00332909. DOI: 10.1037/bu10000127.
- [20] K. Murayama and A. J. Elliot, “The competition-performance relation: A meta-analytic review and test of the opposing processes model of competition and performance,” *Psychological Bulletin*, vol. 138, no. 6, pp. 1035–1070, Nov. 2012, ISSN: 00332909. DOI: 10.1037/a0028324.
- [21] O. Ganai and S. M. Ledbetter, *How to Motivate With Leaderboards: Stop Accidentally Making Losers*, May 2018. [Online]. Available: <https://medium.com/practical-motivation-science/how-to-motivate-with-leaderboards-da5a461fb2f6>.