Designing a personalized learning app

for math courses in elementary school

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Abstract

This thesis tries to investigate how to support personalized learning of math for year 6 students in elementary school through the development and evaluation of a web app. The purpose of the web app is to improve the learning experience for young students with a focus on adaption to each individual student's level. The design aims at creating a fun and motivating learning environment that creates confidence towards learning mathematics. The study is based on previously conducted research within learning experiences for students using apps, designing educational apps for children and gamification and motivation. The thesis covers the process of design and implementation of an educational web app in cooperation with students and teachers. Results are attained through user tests of prototype and MVP, interviews and questionnaires. The evaluation result indicated that when designing a web app where users advance academically, it is essential to have a high quantity of questions in each level. This ensures that all students are engaged in the educational content. Including game-based elements was an effective tool to keep users motivated. These elements should be related to the educational content in order to support learning and not become a distraction from it. It is strongly recommended to include hints and explanations to mathematical problems, since these help students in solving difficult questions. Hints and explanations especially accommodates users with low confidence and excitement towards mathematics.

Keywords: Game-based Learning, Children, Website, Web App, Mathematics, Educational Apps, Primary mathematics.

Contents

1 Introduction

Online learning has evolved from being a trend to becoming the norm in educational institutions. The learning environment is no longer bound to the classroom, but instead students are given the opportunity to choose where, when and how they want to study. This development together with the recent impact of the global pandemic has presented teachers with a new challenge, which is the responsibility of accommodating lessons to be as worthwhile in person, as they are online. Alternative forms of education, which are able to keep the attention of pupils throughout the day is therefore in high demand. The use of technology in mathematics has a long tradition and has thus been broadly discussed. The impact of technology on teaching and learning of mathematics is the topic of a wide range of research and continues to be of interest to researchers [2].

Compared to other subjects, mathematics has the least positive level of student motivation. This is because it is the area of the curriculum in which success and failure are most prominent and obvious[17]. In a time where students are, more than ever, left to self-study it is important to create tools that can encourage and motivate students. Furthermore, there is a clear need for learning experiences that are customized the individual student, such that no student is left with the feeling of being neither inadequate nor unchallenged. The aim of this thesis is to create a comfortable and safe space that invites the student to be curious, challenged, entertained, and engaged. Taking a user-centered design approach, this thesis focuses on taking the reader through the process of identifying the main problem and user requirements, implementing an educational web app, and finally evaluating the app's design, usefulness and functionality to understand whether the developed solution solves the problem and covers the user requirements.

1.1 Problem statement

Problem statement: How can an app support personalized learning of math for year 6 students in elementary school?

Project description: This thesis investigates how to improve the learning experience and outcome for young students with the use of a learning app, which aims to have ethics and children's best interests at it's core. The app also focuses on adapting to each individual student's level, and how the design of the app can be a fun and motivating space for young students by including elements of gamification.

Intended learning outcomes:

- Analyze perspectives on how to motivate the target group in a fun and engaging way to achieve good learning experiences and outcomes in math.
- Design and implement a math app with focus on personalization and gamification.
- Evaluate the math app's design, usefulness and functionality.

2 Previously conducted research

In this section, the problem domain is presented through the exploration of previously conducted research. The research included focuses on the following themes: 'Learning experiences for students using apps', 'Designing educational apps for children' and 'Gamification and motivation'. These themes were chosen because they frame the initial problem statement well, and because they provide a foundation of knowledge within the domain, to aid in making competent design choices for the educational web app implemented later in the process.

2.1 Learning experiences for students using apps

This section examines how technology can impact mathematics education. The research includes studies with children of differing ages and examine the use of varying digital resources. Some articles include the design choices behind different digital resources, and all papers cover the benefits and downsides of using technology in teaching.

There's an App for That: How Two Elementary Classrooms Used iPads to Enhance Students Learning and Achievement

In this article the interaction between education and technology is observed by teaching math and languages in different ways to two groups of 6-7 year-old 1st year students in California. One group used iPads to learn in the classroom and played a mathematics game called Alien Equation. The other group learned in a more traditional manner without the use of iPads.

After a three-month period, they conclude that the class using iPads had much higher learning outcomes, than the class being taught traditionally. The difference between the students' abilities was especially evident in the subject number sense, which covers addition, subtraction, number identification, multiplication, and division. Here the students playing Alien Equation scored 19 points higher on average compared to the class learning without the game.

Even though students had great results in terms of learning outcomes using the iPads, teachers experienced challenges with the technological aspect of teaching. The iPads often became a distraction for students and in order to prevent this, teachers had to take many time-consuming measures. One of these were mentioned to be much prior planning to effectively incorporate the iPads in lessons. So incorporating digital resources can be difficult for teachers, especially when teaching younger students, who tend to be distracted more easily. Lastly, both teachers in this study were in their late twenties, which might make the technical part of teaching with iPads less of a challenge than for someone older and less experienced with technology [14].

Analyzing the use of mathematics apps in elementary school classrooms

Another study in Ontario investigates the learning performance of students, who are using mathematics apps more in depth, by analyzing the acquiring of specific types of knowledge. They also examine teacher attitudes towards mathematical apps as well as including students' prior ability level as a factor.

This study involves 127 students ranging in age from 8 to 11 from grade 4, 5 and 6 and also 6 teachers of differing ages. They use 5 different apps from the Explore Learning Collection that focus on probability, percent, decimals and fractions. The data used was produced through questionnaire feedback from students, teacher workshops, written guides and tests before and after letting students use the apps for 20-90 minutes.

The attitudes towards the use of mathematical apps among teachers was very positive and they thought the apps made learning engaging and fun for their students. Students were less enthused about using apps than teachers, but generally liked including them into the lessons. The students had an increase in short-term performance in all specific knowledge areas after using the apps, especially in analyzing and remembering.

Some studies suggest that students with lower ability benefit more from using mathematical apps than students of higher ability, but in this study neither gender, ability, grade level or student attitude was linked to learning outcomes. It is speculated that this is because of the quality of the math apps used in the study, that challenge all math abilities and accommodates different types of skill-sets within mathematics [10].

Reshaping the Learning Experience Through Apps: Affordances

This paper reports on how affordances of apps reshape the learning experience in primary-school mathematics, especially in contrast to pencil-and-paper technology. One of the affordances with use of mobile technology mentioned in the paper are the notion of multiple representations e.g. the ability to link and simultaneously interact with visual, symbolic, and numerical representations in a dynamic way. Another is the propensity to give instant feedback to input, which transforms the nature of the learning experience compared to pencil-and-paper technology. A third is focused restraint, in which the app might focus student's attention on particular mathematical concepts or processes.

According to the paper, apps' affordances of interactivity and instantaneous feedback foster the student's willingness to take risks with their learning. Students commented that they felt more confident doing math, because of the immediate feedback, which gave them the assurance that they had a correct solution. While these opportunities could be enacted through other media, the paper argues that it is the ease of use and the fact that the features are integrated into one device that seem to facilitate these processes more easily. Finally, the authors note the fact that the students can decide where and how they work enable a sense of personalization of the learning space, and help facilitate a sense of ownership with their learning [1].

2.2 Designing educational apps for children

In the following section we examine important aspects to take into account, when designing technology for young students learning mathematics. The first two papers provide us with a formative guide of the design, while the theory of 'learned helplessness and mastery oriented students' gives us an understanding of student engagement in learning mathematics. Finally we look at the importance of involving children in the design process and specify features that young users find essential.

Design Principles for Children's Technology

The paper presents a catalogue of design principles specifically oriented towards designing for children based on a wide range of research on technology developed for children. It is strongly emphasized that design principles for adults do not apply for children's interfaces, and designers must adapt interfaces to children's development, skills, abilities, and expectations. Children's technology must be designed with a narrow age-group in mind to sufficiently meet the needs of its users.

The benefit of using animated on-screen characters is strongly emphasized. In this study, animated on-screen characters who guide, encourage, or entertain children are useful for learning environments. It is shown to positively affect 12 to 14 year old children's experience and encourage them to use the software more frequently. Benefits such as increased learning occurred when the character was expressive and offered domain-specific advice and explanations.

Another key factor in the design of children's technology is the use of extrinsic rewards such as multimedia messages, scoring systems, and bonus activities. Rewards should be consistent and available even if children repeat the same problem or activity level as they will need to re-experience success to gain confidence for moving forward. The study found that 6-17 year old children wanted a score display, and, in it's absence, they kept score themselves by counting.

Finally, the paper claims that children's technology should facilitate interactions between children. Research found that children at the age of 10-14 years, requested the feature to communicate digitally with others while doing tasks, even if they were sitting together. In the absence of such a feature, they instead alternated between two applications, the learning application and an instant messenger [3].

Designing for Children's Rights Guide

The global non-profit association Designing for Children's Rights consists of a group of designers, researchers, psychologists and experts on children's rights and protection [7]. The association work together to create awareness about the importance of keeping children's rights in mind when building products and services. In 2018 (revised in Feb. 2021) the association developed a set of principles in the form of a guide for ethical design for children's rights. The principles are written from the perspective of children as consumers, to designers of products for them. The principles defined are formulated in first person, and are focused on inclusion and encouragement. Some of them are: Give me room to explore and support my growth, create space for play, include a choice to chill, encourage me to be active and play with others, use communication I can relate to, and you don't know me, so make sure you include me. All principles together with a short description of each of them can be read here [18].

Teacher Identification of Student Learned Helplessness in Mathematics

Students with learned helplessness are a huge challenge for teachers when teaching mathematics in school. Learned helplessness is describes as having a negative attitude towards learning, and a belief that the student is powerless in influencing the outcome of their own learning. Students with learned helplessness believe that they will never be successful in different subjects, such as mathematics, because of their perceived lack of ability. Because they believe that learning mathematics is related to ability rather than effort, they end up decreasing their effort or simply giving up when met with challenging assignments. By contrast, mastery oriented students believe that success is determined by effort. They are positive towards learning and prefer challenging assignments. Learned helplessness is more common in mathematics because success and failure are more obvious.

Because students have learned to be helpless, it is also amenable to change. Therefore, it is important that teachers identify students who exhibit this characteristic and especially at the primary school level before the negative behavior becomes entrenched [17].

Designing effective educational software: Involving children in the design process

The following study examines how involving children in the design process of educational software impacts their motivation and learning outcomes. The study was conducted in Denver and involves 63, 10-11 year old students from grade 6.

Two different math programs were designed, one by children, here 8 students, and one by adult designers. The students immediately agreed that the software should be a game involving characters and plot-driven stories. The students also chose not to have a timer, since they found it to be frustrating. Adult designers chose to include a timer since they felt it would motivate students and they decided to not include a range of characters. Both programs had help screens, but in the designers' program it would pop-up after users got three questions wrong, whereas students chose it to be voluntary. The content of the programs was identical, and all students used the same amount of time in the two different programs. Students playing the game designed by children had a significantly greater increase in ability in fractional knowledge compared to the students using the adult designer's program. This stresses the importance of not only knowing your user when designing educational software, but also including them and using their ideas in the design process [15].

Child-Centered Design: Developing an Inclusive Letter Writing App

How to design software for children is the main subject of the following study, where an educational language app that combines technology and gamification is designed in an iterative process. The goal is to make the educational aspect of the app entertaining, as well as creating a child-centered and inclusive product. This goal is fulfilled by including children

directly in every step of the design and implementation process by using both cooperative inquiry and co-creation.
The app was developed using a prototype test, a redesigned prototype and a focus group with children and teachers. These user-tests were done to empower the children to participate actively by sharing their ideas and opinions. The study concludes that visual cues are important feedback for children, and was related to increased ability to navigate the software and better user-experience. It makes it easier for users to decode meanings and gave the children an improved user-experience. The app in the study also ended up including rewards for progress, which proved to be a compelling reason for children to use the app. It added both surprise and anticipation to the user-experience while learning educational content. The app excluded loud sounds when getting something wrong or right, since children found them upsetting and distracting. The sounds included in the final app were of low tones [13].

2.3 Gamification and motivation

In the following section the impact of integrating game-based elements in digital educational resources is examined. The research presents the characteristics of different game elements and how to implement them into educational tools in order to engage and motivate students in their learning experience. Benefits and disadvantages are put forward together with comparisons of traditional and game-based learning.

Educational learning in informal learning environments - a practical example of games as a learning context (translated)
In this article the use of game-based elements as motivation for learning is explored. The online game "The fight for feedstock" is used as a case example on how to bridge between an informal learning environment and the school's curriculum with the use of gamification. The study involves students at the age of 14 to 15 years old. The game elements are explained as including time limits, the possibility to advance in levels, and collection of points and prices. The study shows that the gamification heightens the student's participation and motivation, attention is maintained for longer, and a small gain (mean of 5.2%) in content knowledge is found. The disadvantages of gamification as motivation for learning is described as the risk of having the competition overshadowing the curriculum learning. This is mentioned as something that can prevent the experience of understanding and contemplation, both are important when learning new topics. There is also a risk that students only put as much time into the curriculum content as demanded to continue to advance in the game. This requires teachers to know the degree of competitiveness in the class before introducing game-based elements as motivators for learning, since too much competitiveness can distract from the educational content [16].

Constructing a gamed-based learning website for children
The article explores the effect of game-based learning through an evaluation of a museum game website targeted at children. The study includes 47 primary school children, 27 boys and 20 girls, and data is collected through questionnaires.

The results indicate that game-based learning websites can inspire learning motivation and enhance learning effectiveness for children. Game-based learning is described to include play, rules, goals, interaction, adaptiveness, feedback, win states, challenge, problem solving, representation and story. The article claims that the visual effects of these types of websites features the charisma of fairy tales and aesthetics design, which appears attractive to children's visual senses. It also stimulates their motivation to keep on exploring and learning. The advantage of including features such as accumulating virtual rewards through completion of missions, is that it encourages children to proceed with the challenge while obtaining a sense of achievement and satisfaction. The evaluation of the museum site shows that children prefer designs of accepting missions, virtual characters, and interpersonal interactions.

A high interactive approach offers advantages such as increased interest, lower learning obstacles, memory retention, the cultivation of critical thinking and problem solving [5].

Effects of digital game-based learning on students' self-efficacy, motivation, anxiety and achievement in learning mathematics

For many students, math remains somewhat of a forbidden course, and it can effect students learning outcomes negatively. This is one of the motivations for the following study involving 69 students that explores how game-based mathematical learning environments can reduce students' mathematical anxiety and improve their self-efficacy and motivation to learn mathematics.

In this study the students were parted in to three groups of 23, one group used digital game-based learning, another used technology-enhanced learning and the last used traditional learning methods. The students completed a 240 min learning activity with their assigned learning category with both pre- and post-testing. The groups using digital tools had significantly higher self-efficacy than the groups using traditional methods of learning. This can be explained through the digital tools' ability to encourage students more effectively with instant feedback. The group using game-based learning showed substantially higher motivation for learning than both the other groups. Even though there was no significant difference between the three groups in terms of mathematical anxiety, the digital based learning activities resulted in slightly lower ratings, whereas the students doing traditional activities reported slightly higher anxiety ratings. This suggests that the digital game-based tools have the potential to reduce anxiety and increase confidence and motivation around learning mathematics [6].

Implementing a game for supporting learning in mathematics

In the following study a mathematics game is developed to explore how to incorporate computer game elements like challenge, fantasy, objectives, interaction, and curiosity into learning mathematics. The game implemented was designed to engage and motivate students to learn and explore mathematics in a fun way. This was ensured through different game principles, like interaction, feedback, and gradual progress. This gradual progress was designed to be adaptable to the students' level, so each student would progress at their own

pace. The game also included characters, a storyline, and a score-keeping mechanism.
This game was used by 37 students aged 12-14 over a 14-week period. Their feedback was mostly positive, and they found the game both engaging and motivating regardless of gender and age. The game-based learning activities helped the students understand complex problems better and they appreciated the innovative and playful approach to learning. The explanations of certain math problems in the game were not sufficient in some cases, and students preferred help from a teacher as opposed to using the help and explanations provided in the game [9]. This shows that defining clear and well formulated hints and explanations are essential in order for them to be useful to students, and that sometimes asking a teacher is necessary for understanding a problem.

3 Solution

This section details the process of designing and implementing the educational game-based web app, Maths Camp. The solution is our suggestion on how to support personalized learning of math through a web app. First, an overall approach to the development is introduced, and the functional requirements to the solution are defined. Then, a prototype of Maths Camp will be presented, and the results of a user-test of this prototype will be analyzed. Consecutively, data storage and the system architecture will be discussed. Finally, the user-interface of the Maths Camp will be shown.

3.1 Process

When designing and implementing Maths Camp the main focus was a user-centered approach. This supported our ambition to create a web app that was both entertaining, useful and inspired confidence surrounding mathematics. We approached the project in three main steps: Defining the problem, implementing a solution and evaluating the solution.

Previous research was explored and analyzed with the aim of obtaining an understanding of the problem domain, namely educational software, designing for children and game-based elements in software. This knowledge was in combination with the expertise knowledge from a teacher stakeholder from Halstead Preparatory School for Girls located in Woking in England, used to create an initial outline of our personas, functional requirements and design of the prototype.

Our user-centered approach inspired us to conduct a user-test of the prototype, which revealed additional insights into what factors were important to users when using an online web app to learn mathematics. This made us reiterate our design choices and prioritization of the functional requirements before the solution was implemented in React. We created a comprehensive design library in Figma, a user interface design tool, which resulted in a very clear definition of what components were necessary in our web app, and how these were supposed to look. The mathematics questions used in the practice mode of the web app required expert knowledge, and to define these we again collaborated with our teacher stakeholder who provided us with several mathematics papers and online resources to use in Maths Camp[1] [2]. The online resources consists of primary mathematics challenges. This collaboration also allowed us to construct five fundamental mathematics categories for the questions and include quality educational content.

After creating a minimal viable product, we deployed it through Github and introduced it to two teachers and their students, one in an International school in Copenhagen, Denmark and one in Woking, England. One of the classes used the web app for one week, and the other for two, and 48 users participated in the user test in total. For the evaluation we created a questionnaire for the users that took part in the test and collected screen recordings of their interactions with Maths Camp through Hotjar. The replies and recordings were analyzed to determine which elements could be improved in our solution to enhance the user-experience

[1] https://www.primarymathschallenge.org.uk/downloads
[2] https://www.ukmt.org.uk/competitions/solo/junior-mathematical-challenge/archive

and support our goal to create a fun and safe learning environment for children of all skill levels in mathematics. Finally, we conducted interviews with the teachers of the two classes, and used this to gain a deeper understanding of which elements could enhance the usability of Maths Camp.

3.2 Personas

We chose to create personas because it support our user-centered design and also provided us with important knowledge about our users, their behaviors in and outside of the classroom, their attitudes towards learning, their needs, and goals[4]. The two personas were created early in the development process, and since our initial idea was to develop a product specifically for our English stakeholder teacher, they are both primary school girls from Woking. The personas are based on the previously conducted research, especially the theory of learned helplessness and mastery oriented students, helped us understand how users behave when learning mathematics[17]. We also gained knowledge through meetings with our teacher stakeholder that informed us about her students, their interests, educational goals and hobbies. Finally we explored the Halstead Preparatory School for Girls website and the English school system in general to get a better understanding of the environment our personas were situated in. Copyrights of images used in the personas belong to the authors.

ALICE

DEMOGRAPHIC

Age: 11

Education level: Primary Six, Halstead Preparatory School

Home: Woking

ABOUT

- Visual learner
- Plays Roblox in her spare time
- Uses Facebook and TikTok

MOTIVATORS

- Good grades
- Recognition from teacher and parents

UX NEEDS

- Visually pleasing
- Simple language
- Colourful
- Motivating
- Game-like

PERSONALITY

Alice is a social intelligent child with four siblings and a lot of friends. She spends a lot of time outside with her friends and plays rugby twice a week. She is very insecure about her maths skills and believes she will never be successful at maths because she doesn't have the abilities.

EXPERIENCE LEVEL

Alice is a digital native and she uses her phone for several hours each day and sometimes plays games on her parents' iPad or computer.

CHALLENGES

- Finding the motivation to do maths homework after school
- Sitting still for too long
- When met with challenges in learning she gives up easily
- She lacks self-esteem in maths and believes she will never be good at maths.
- Responds badly to failure.

CONTEXT

- Alice will use the web applications in lessons when her teacher asks her to, and outside school when she does her assigned homework with her classmates.
- She will only access the web application when she needs to.
- Alice will access the web app on desktop at school and on iPad at home.

USER STORIES

- "I want to be better at math so my classmates don't think I'm dumb."
- "I want my practice to be anonymous so might classmates can't see how bad at math I am."
- "I want to be able to pick a cheering mascot so that I can be motivated during practice."
- "I want to be able to see a hint when doing a task, so I don't get stuck and get frustrated."
- "I want motivational messages if I spend too much time on a task, because I might otherwise give up."
- "I want to start each session by answering easy problems, because I need some encouragement."

EMMA

DEMOGRAPHIC

Age: 11

Education level: Primary Six, Halstead Preparatory School

Home: Woking

ABOUT

- Loves school and learning
- Plays tennis and the piano in her spare time
- Uses Instagram and Snapchat

MOTIVATORS

- Good grades
- Challenging maths problems

UX NEEDS

- Personalized learning, that adapts to her fast pace and progress
- Motivating and rewarding
- Goal oriented

PERSONALITY

Emma is an ambitious, competitive, detail-oriented, and dutiful girl who loves to learn and strives to make progress. She doesn't believe in talent but views her progress as a product of her hard work and practice.

EXPERIENCE LEVEL

Emma is digital native and can easily manage several kinds of technology. She is allowed to use her phone for an hour each day, which she uses to chat with her friends on Snapchat.

CHALLENGES

- Lack of motivation when maths problems get too easy

CONTEXT

- Will use the web application in lessons when her teacher asks her to, and outside school when doing assigned homework. Since she is a competitive person, she will also want to use the web app in her spare time to be the first in her class to complete all categories (level 3)
- Will access the web app every day until she has finished all categories
- Will access the web app on desktop at school and on iPad at home

USER STORIES

- "I want to progress in math because I want to get the best grade in my final exam."
- "I want to progress in math because I want my parents to be proud of me."
- "I want to be able to see and show my progress in math because I want to show it to my teacher and parents."
- "I want to be able to do mock exams because I want to see how far I am from attaining my goal (passing math exam)."
- "I want a reminder to let me know, when it's time to go outside because I tend to sit too long in front of the computer."

3.3 Functional requirements

The functional requirements were defined in collaboration with our English teacher stakeholder. Initially, many ideas were detailed and included as requirement initiatives. It was decided that the web app should be a personalized mathematics web app with game elements that could prepare 10-11 year old students for exams through practice of different maths problems. The initiatives were categorized into teacher and user initiatives, and subsequently into four different prioritization levels derived from the MoSCoW method: must-have, should-have, could-have or wont-have [8]. The prioritisation of the initiatives have changed several times and the reiterations of the initiatives ended up being an essential part of finding the core focus of this project. They also introduce the context and focus of the web app implemented in this project. The initiatives are clustered by importance.

3.3.1 Requirements for users

Functional requirement initiative	**MoSCoW prioritisation**
Users can log in	Must-have
The practice mode will provide users with random questions that fit their level by keeping track of the user's number of correct answers in each category	Must-have
Users can collect points	Must-have
Users can buy mascots and pick a personal mascot for the practice mode	Must-have
Users can choose to reveal a hint while they are picking an answer	Must-have
Users can see an explanation on how to solve the problem after submitting an answer	Must-have
Users can see an overview of their progress on the front page, like the total amount of points they have, the total amount of questions they have answered and total number of days played	Must-have
Users will get motivating messages after answering a question	Should-have
Users can obtain rewards which also earn them points	Should-have

The system counts the amount of time a user spends on an exercise and the mascot will give them encouraging messages after some time	Could-have
Users can choose between a practice and a mock exam mode	Could-have
Users can use points to buy accessories for their mascots - such as hats, pets, new hair etc.	Could-have
The system counts the amount of time a user spends in the practice mode, and after 20 minutes they will be redirected to a page encouraging them to take a break	Could-have
Users can show the explanation of a previously correctly answered question when they press the hint button (if such exists).	Could-have
Users can change background color of the practice component for their points	Could-have
Users can share rewards with friends on social media	Won't-have

3.3.2 Requirements for teachers

Functional requirement initiative	MoSCoW prioritisation
Users can log in	Could-have
Users can add and remove questions, answers and explanation where they have to pick a level and a category	Could-have
Users can create a class	Could-have
Users can add users to a class by using their name, and then a username and password will be generated	Could-have
Users can see statistics about users progress. Users are anonymous in these statistics and could include levels in different categories or most wrongly answered questions in different categories	Could-have
Users can print out login-cards for users	Could-have

Since the teacher interface was merely for managing questions in the database and getting some feedback about their student's progress, it would only be relevant to develop this, when it was certain that the students actually enjoyed using Maths Camp, and were motivated to learn mathematics in the setting of this web app. Therefore we decided to prioritise all teacher related initiatives as could-have initiatives. This meant that we could implement

these initiatives if we had time, but they were bottom-priority and allowed us to focus on the student interface.
The student related initiatives were changed both after the first prototype test where we got a clearer understanding of what was important to them, but also during development where we abandoned certain initiatives to focus our time on increasing the quality of other initiatives.

3.3.3 Game concept

Including game elements in the web app harmonized well with the initial ideas for the web app and were considered a way to engage and motivate users to learn mathematics. One of the central goals in creating an educational mathematics web app is to make it fun and entertaining for users to learn and explore new topics. A way to accomplish this is through the concept of earning rewards and points. The game elements are a part of the considerable amount of feedback users get from the web app. Users are also able to pick a mascot, which is designed to make the web app feel more personalized. Both allow users to be actively involved in their own progress and can be a factor in maintaining their motivation to use the web app. When defining what advancements in the game should be rewarded, it was important that these were attainable within a time frame of 2 weeks period assigned for user-testing.

Points
The web app includes a practice mode where users get questions in different categories that fit their level, so it was an obvious idea to reward the user with points when answering a question. It was decided that a user would earn 10 points for a correctly answered question, and 5 for answering a question wrong. This was done in order to give users a sense of accomplishment and confidence, even if they didn't get the question right on the first try.

Mascots
Another way to cultivate motivation and add a sense of personalization when using the web app was to include the option of picking a mascot. This mascot was also responsible for a different kinds of feedback to keep user's engaged, such as hints and motivational messages when answering questions in practice mode. To further add a challenge to attaining mascots, it was decided that users would be assigned a default mascot when registering, and then mascots should be unlocked by buying them for points. The 24 mascots were grouped into three groups of 8, costing respectively 100, 150 and 200 points.

Badges
Lastly, users can earn badges for different tasks related to their progress. The 25 badges ended up being separated into 5 different categories containing 5 badges each. The first category is related to the total number of mascots a user owns. Here it made sense to earn a badge when owning 3, 5, 7, 9, and 11 mascots, since it seemed realistic to earn enough points to buy this number of mascots within the time frame. For the 5 badges connected to

total number of days played, the badges would be earned after playing for 3, 5, 7, 11, and 15 days. For the last three categories: total number of questions answered correct, total number of explanation checked, and total number of questions answered, the badges would be earned for answering or checking explanations for 5, 20, 50, 60, and 80 questions.
Earning a badge comes with a side reward of 50 points. For each category containing 5 badges, the last badge was rather difficult to earn, and the first was quite easy. This was chosen such that the easy badge acted as a quick payoff to incline users to try to earn the next badge. The difficult badge was meant to create a sense of authentic achievement when earning the badges.
It was also decided to include a small overview on the front page where users can see total amount of points, total number of days played and total number questions answered, gives users a chance to follow along in their process in between earning badges.

3.4 High fidelity prototype & visual design principles

The following section explains the design process behind our initial prototype. The prototype was designed in order to get a clearer picture of what we wanted our web app to look like and how the defined functionality would be presented in practice.
We began the design process by doing visual research in the form of a digital mood board. The mood board consisted of images of different children's games and movies together with colors and icons. We also examined already existing online educational apps and tools targeted towards children in our users' age group. Here we got inspiration for the site layout and architecture, and it especially influenced our decisions when it came to the set up of mathematical questions. Some of the apps visited were: BrainPop, GameUp, DIY.org, MatematikFessor, Brilliant, CK12.org, Gizmo, and Khan Academy.
We brainstormed ideas and themes for our app. We wanted to create an enjoyable and welcoming space for our users that gave room for both contemplation and play. We came up with the theme scout camp, and thereof we named the web app Maths Camp. We found that the badges and mascots associated well with the theme, and thought that the combination of the theme and the game elements encouraged creativity, curiosity, interaction, goals, win states, competition, challenge, and problem solving.
When designing the interface for Maths Camp we used the previously conducted research presented in section 2 as a formative guide [3] [18] [15]. We gathered a set of design principles in order for us to have a clear direction during the design process. This also ensured a final result that looked coherent, and a product that is directly oriented towards children at the age of 10-11 years:

- Text shall be assisted by graphical metaphors (eg. icons).
- Icons shall be visually meaningful to children.
- Rollover animation and highlighting shall be used to indicate where to find functionality.
- Interface shall focus on being visual with a minimum of text.

- All forms of communication shall be accessible for everyone (in age group).
- System shall be intuitive without the need for instructions.
- Users shall be able to see results of their actions immediately. Auditory or visual feedback shall be implemented.
- Mouse interactions shall be simplified. Point-and-click interface rather than drag-an-drop.
- Occasional entertaining diversions shall be implemented to keep children engaged and motivated during learning tasks.
- Timer shall not be visible as this is found to be frustrating.
- Pop-ups shall be limited, since it is found to be distracting.
- Animated on-screen characters shall guide, encourage, or entertain. Characters shall offer advice and explanations.
- On-screen characters shall not be intrusive and their comments shall be appropriately timed to complement current activities or prepare users for what is about to happen.
- Extrinsic rewards shall be used in the form of a scoring system and bonus activities.
- Rewards shall be consistent and available even if children repeat the same problem or level.
- The learning environment shall put the users in control, let them set and achieve goals and be part of the action.
- Fun features, such as reward reviewing and break pages, shall be embedded to allow users to take breaks from the main task.

3.4.1 Colors

We used the Adobe Color Wheel for our color selection [19]. Inspiration was found in existing web applications and games targeted children. What these web applications had in common was a colourful palette with bright, vibrant and solid colours. We chose four colors, both primary and secondary. We also added shades and tints to each of them, to for example clearly indicate buttons that are being hovered. Besides white, grey and black we also found it necessary to add a green colour to indicate when a question was correctly answered.

Figure 1: Color palette

3.4.2 Typography

Solway was chosen for headers, while Rubik was chosen for the body text and buttons. We chose to combine a sans serif with a serif font to create contrast, but both fonts are also similar in the way that they are both characterized by their round corners, which gives Maths Camp its welcoming and friendly appeal. It also makes the web app feel less formal and can invoke a sense of playfulness. Most text, especially on buttons, is supported by an icon in order to create a visual language that is easily interpreted by children. This can help users navigate the interface[3].

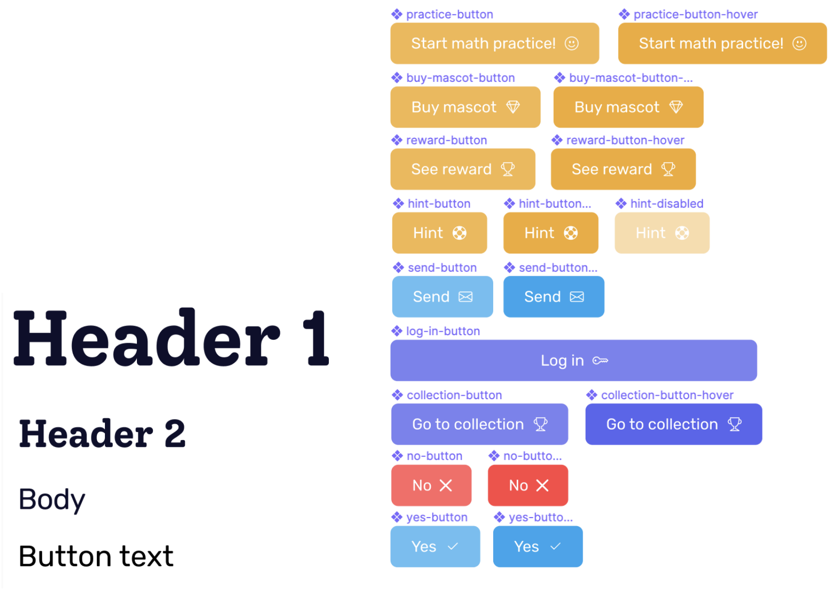

Figure 2: Typography and buttons with icons

For this project we created a team library in Figma. This was done to easily share styles and components across files in Figma. The library can be accessed here[3]. Finally, we built our prototype in Figma based on all the research work and the design library. The high fidelity prototype can be accessed through Figma here[4].

3.5 Usability test

The purpose of the usability test was to analyse the high fidelity prototype for usability problems and to test whether the design choices we made resonated with our target group. The prototype used in the usability test can be accessed here[5]. Note that the prototype is translated to Danish to accommodate the Danish speaking test group. The English edition can be accessed in the previous section. Our test script for the prototype usability test can be found in the appendix (6).

3.5.1 Test users

The first user test was conducted at the Danish school, Hældagerskolen, located in Vejle. In collaboration with mathematics teacher, Finn Nørgaard, we chose four users from the 4th grade with different mathematics levels[6].

3.5.2 Test report

Maths Camp, Figma prototype, high fidelity
Usability test 27.09.2021. Test users: K, H, S and A

[3]https://www.figma.com/file/5gpUFCeAshpQK5JlOo3mT5/Math-web app-team-library
[4]https://www.figma.com/proto/sbLFd15cmWerEUzbALYjk7/Prototype
[5]https://www.figma.com/proto/ckNvdgSwyx0J7PCKIw5JAC/Prototype
[6]We chose 4th grade since users in this grade correspond in age to Year 6 in Primary School in England

Observed problems is classified with severity classes[12].

Problem 1: (A: Minor problem)

During quiz: Had trouble finding the explanation button. Tried to click on the speech bobble by the mascot. Found it eventually, but thought it could be more clear.

Problem 2: (S: Minor problem)

Practice page: Had trouble understanding where to find help at first. After a short while she realized that she should press the hint button.

Problem 3: (H: Minor problem)

Mascot page: Not clear what the price of the mascots means.

Problem 4: (H: Minor problem)

Mascot page: When picking a new mascot: She thought she had lost the mascot she previously owned. Needed a clear sign of “owned” vs. “able to buy”.

Problem 5: (H, S, A: Medium problem)

Mascot page: Not clear that they needed to pick a mascot after buying it.

3.5.3 Reflections

The usability test revealed that our visual design and game concept was appreciated by all participants. They had some comments on how to improve the design and additional features that they wanted to include.

All users requested more customization of the system such as the option of buying accessories for the mascots, like different hair, hats, clothes, and pets. They also requested the possibility of changing background to personalize the web app. We listed these requests as could-have functional requirements, since our development time-frame was rather short and decided to prioritize more crucial features.

We presented a selection of mascots to the users, including animals, monsters and people (see Appendix 6). Many of them thought the animals were cute, and they also liked the children, so both of these were good options. In the prototype we included four mascots, and all users agreed that they wanted more and different mascots to choose from. We chose to adhere to this and included 24 mascots instead of the initial four. One user (A) preferred animals over humans, but as most of our users preferred mascots that represented themselves, we went with the mascots depicting children in the same age group. We thought this was because they could identify with the children mascots better than the animals.

A user (S) requested explanations of similar maths problems when they were unsure of how to solve a problem. We chose to take this into account when writing both hints and explanations, but it ended up not being implemented in the final Maths Camp, due to a lack of mathematics expertise. One user (K) requested more specialized rewards that depend on performance. One correct answer should result in a bronze reward, two correct answers in a silver reward and three in a gold reward. We took this into account when developing the design concept, and made different levels of rewards within categories of accomplishments.

None of the participants indicated a wish to share their activity on social media.

In general, we found that our users were very proficient in their use of modern technology and had very few problems navigating our system.

P3, P4 and P5 were all resolved in order to make the process of buying and selecting mascots clearer. We chose to ignore the remaining usability problems as only one user ran into these and shortly recovered from them (P1, P2).

3.6 System architecture

In the following section, the decisions regarding architecture of the code is briefly explained, followed by the data model and a description of the platform used for storing our data.

3.6.1 Code architecture

The GitHub repository with all the code for Maths Camp can be found here[7].
Maths Camp is developed with React.js. The src folder contains all files relevant to the web application. The src folder is further subdivided into folders containing pages, components and images. Our web app has 11 different pages within which the various components are rendered. Figure 3 illustrates our code's architecture. We have omitted the Footer.js component since it is presented in most pages. Each component has an associated CSS file responsible for the styling of the component. App.js defines the HashRouter that uses the hash portion of the URL to keep the UI in sync with the URL. We have used Parse SDK and several libraries such as React Bootstrap, React Router, React Hotjar, React Icons, and Sweet Alert, and others. Mascot and reward images are stored in the image folder, while the rest of the data including mathematics questions are stored in the Parse database. The code architecture can be seen in the following figure.

[7] https://github.com/anneschjoedt/MathsCamp.git

Figure 3: Maths Camp's code architecture model

3.6.2 Data modelling

We chose the open-source Parse Platform for building our web application's back-end. It is hosted on Back4app, a Backend-as-a-Service platform that hosts Parse web applications. We decided on this since it was easily integrated with the front-end, didn't require much set up and was simple to use. This gave us more time to focus on the front-end and the user-experience, and the Back4App user interface of the data made it easy for us to manage and keep an overview of for example the mathematical questions with corresponding hints, explanations, options and descriptions. Below is a figure showing our data model for Maths Camp.

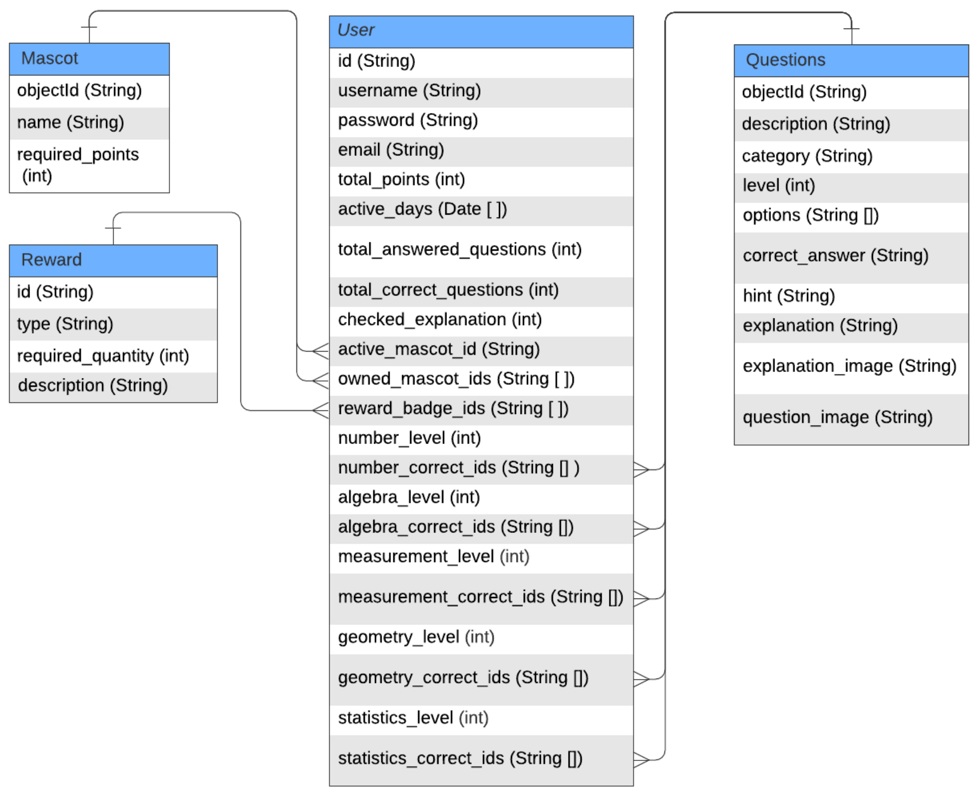

Figure 4: Maths Camp's data model (ER diagram)

The User class stores information about the user and the user's progress during practice. The Questions class stores information about maths questions. The Mascot and Reward classes contain information about the mascots and rewards. Images associated with both are currently stored locally in the image folder, but could be uploaded to Parse as well for consistency.

We used the Parse.User object for storing users into the Parse cloud. Besides retaining the same functionality as a Parse.Object, it also supports different methods specifically developed for registration and authentication of users, as well as validation of uniqueness of

passwords, usernames and emails.
The Parse.Session object is also used in Maths Camp, and "is a local representation of a revocable session" [20]. A session token is created for a user when they log in, and will remain active as long as the user stays logged in. While it is active it acts as an authenticating tool for a users' subsequent requests after signing in, like data relating to their progress.
Due to issues with querying pointers used in relations, we chose to disregard relational classes such as Category, Level and RewardType, and instead hardcoded the categories and levels into the Questions class and the RewardType into the Reward class. This creates some duplicated data in our data model, which is not ideal, but was the only possible solution at development time.

3.7 User interface

In this section the final Maths Camp that was deployed and tested is presented. The Maths Camp web app can be accessed through the link here[8]. It includes a landing page where users can click a *register button* or a *log in button* which will redirect them to said pages. Once logged in or registered, users get to the front page, where they can see their collection of badges, their mascot and an overview of their progress. The front page was designed with the idea in mind that the users should have their own personal space, with the possibility of customization. We wanted to create a learning environment that provided the user with control. The strike table in the bottom was added with inspiration from Snapchat's Snapstreak to keep users engaged and informed about their progress.

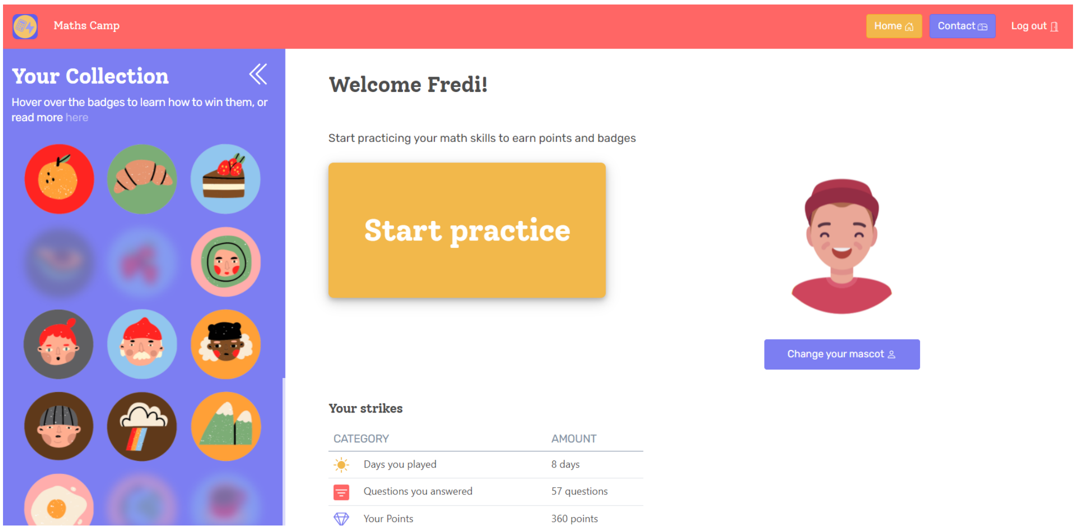

Figure 5: Front page

The sidebar was designed to mimic a scout badge collection and makes up a large part of the front page to indicate its importance. The collection is an overview where users can hover

[8]https://anneschjoedt.github.io/MathsCamp/#

the badges to see what they have to do in order to unlock them, like the sub headline says: "Hover over the badges to learn how to win them, or read more here". The badges that are still locked appear blurred. When users click on the highlighted text "here", they are redirected to the Badge library. Here users can see each badge picture enlarged and with a title explaining how to attain them.

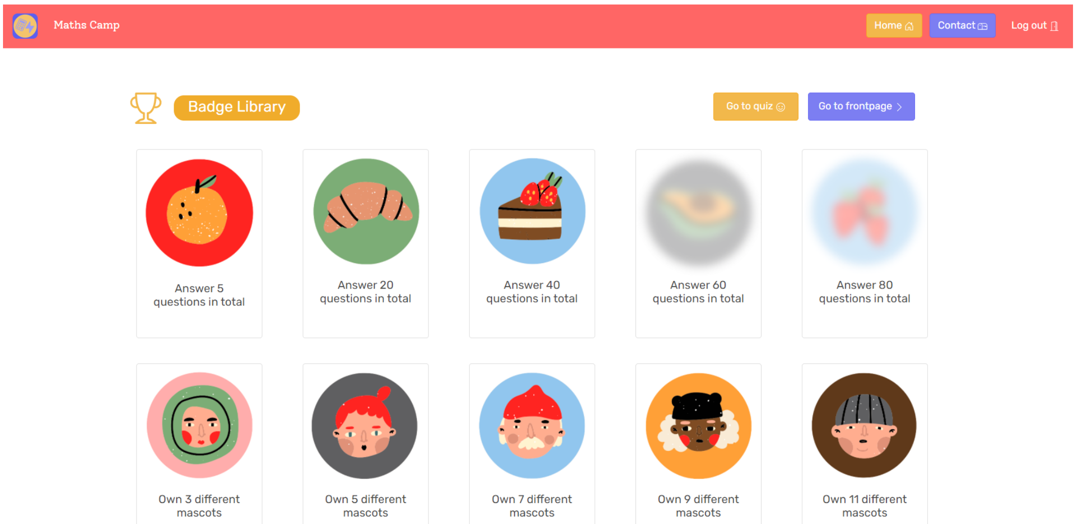

Figure 6: Badge library

When clicking the *edit mascot button* underneath where the mascot is displayed on the front page, users are taken to a page where they can buy and pick the mascots they like. The user's total amount of points are displayed at the top left corner for convenient overview of what they have available for purchasing mascots. The mascot that is currently active has a bright yellow dotted line around it. When a mascot is not owned, it will have a yellow *buy mascot button*, and when owned it has a blue *pick mascot button*.

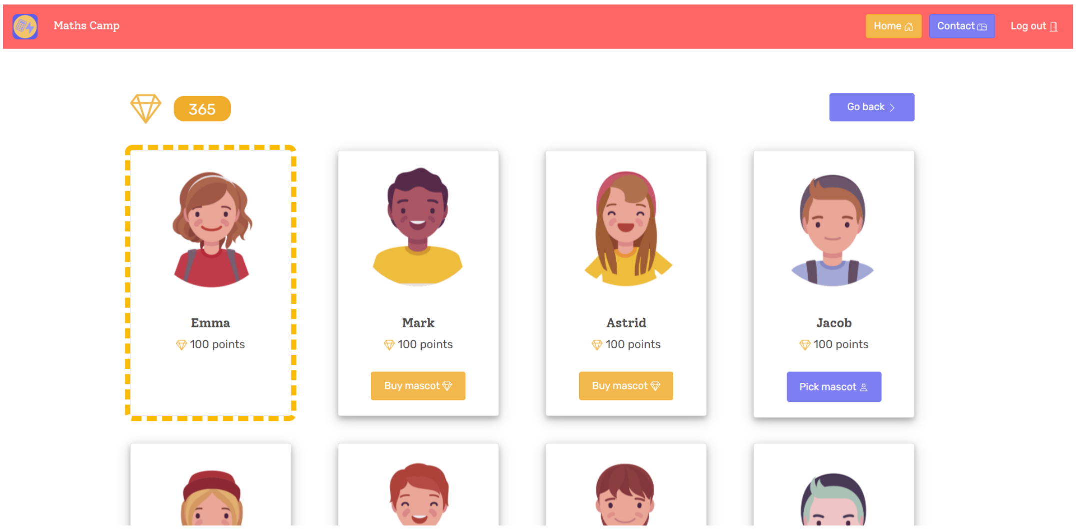

Figure 7: Mascot page

Finally the big yellow *practice button* on the front page takes the user to the practice page. The button was enlarged to indicate that this is the primary activity in Maths Camp. In the practice page they will be presented with random questions from 4 different categories: Number, Algebra, Measurement and Geometry. There are 30 questions in each category divided into 3 groups of 10 belonging to either level 1, 2 or 3. Once a user answers 7 number of questions correctly in level 1 of a category, they advance to level 2 in that category. In the practice mode users can pick 1 out of 5 options, and reveal a hint if they aren't sure how to approach the problem.

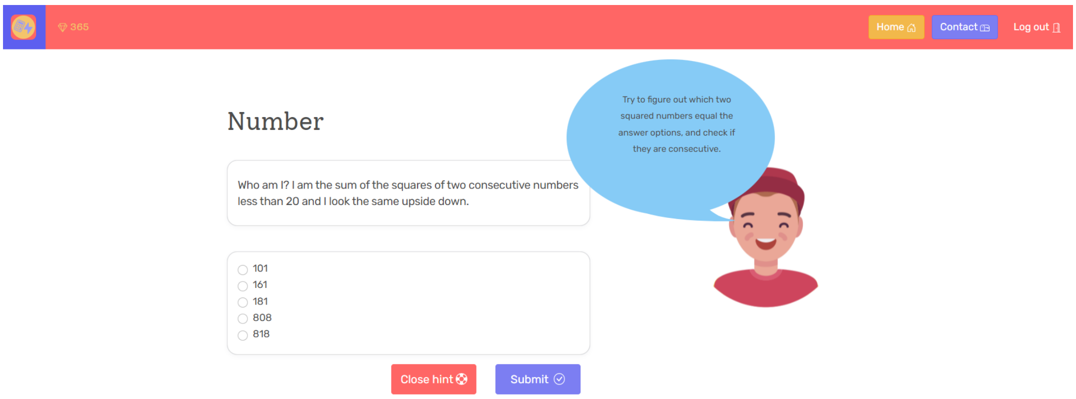

Figure 8: Practice page with hint

When users submit their answer, the option they picked will either turn red or green depending on whether or not they answered correctly. The mascot will give the user some cheerful feedback and furthermore they can see an explanation of why the answer was right or wrong.

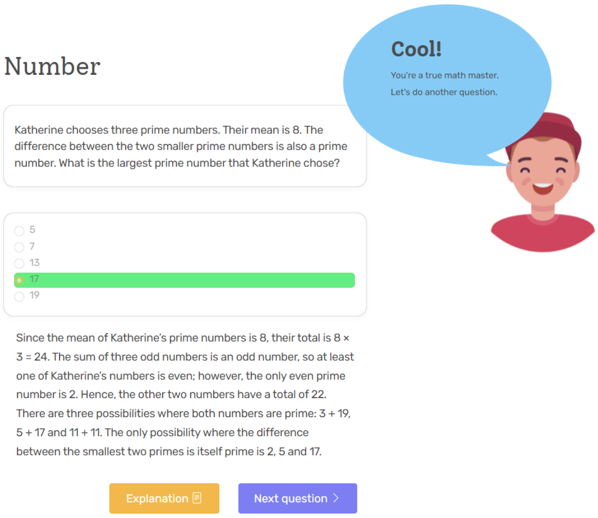

Figure 9: Practice page with explanation

When users are solving math problems they are already under cognitive load, and therefore we attempted to create a simple and intuitive user interface. Users should be in control and have a strong feeling of ownership of their own learning.

As it can be seen on the figures in this section, we prioritized freedom of navigation for the user, and recognition rather than recall. This means that we added a lot of buttons so the user can always navigate back to the previous page, or buttons to take users to the quiz. We also prioritized consistency, which means that we have the same navigation bar on all pages, where the user can navigate to the front page, they can log out or they can go to the contact page.

Additionally we emphasized giving users lots of feedback and visual cues. This means that we added icons to all buttons to make their meaning even more clear. We added blurred effects to locked badges and used colors to indicate active, owned or locked mascots and hovers to indicate mouse interaction. The feedback in the practice page coming from the mascot were included to add an interactive quality to the web app.

Lastly, an alert is shown when users win new badges to make sure users benefit from the motivational game-based elements. In this alert they can either go back to resume where they left off, or click a *see badge button* which will take them to a reward page with a large image of the badge they have won and a congratulations text announcing their achievement.

4 Evaluation

This section discusses the feedback from students participating in the user test of Maths Camp. The feedback in this section aims to evaluate the app's design, usefulness and functionality to understand to which degree the developed solution solves the problem of supporting fun, engaging and personalized learning of math. Here, the methods used to obtain feedback will be described. The feedback data has been collected through three different methods and tools:

1. Hotjar, an online tool to monitor activity on web sites.
2. A questionnaire given to all students participating in the user test
3. Two interviews conducted with the teachers of the classes

The findings from each of these methods will be systematically analyzed and reflected upon. Lastly the main points from the evaluation will be summed up and possible improvements will be discussed.

4.1 Methodology

The methods used in this project reflect the user-centered approach taken in this project. First, the process of the user test and consecutive questionnaire feedback will be described. Then the approach applied in collecting insights from teachers through interviews is explained and substantiated.

4.1.1 User test and questionnaire

The user test was conducted with 48 users from two different schools. The first school is called Rygaards International School located in Hellerup, Denmark and the second is Halstead Preparatory School for Girls located in Woking, England. We worked with a class of 28 International users and 26 English users at the age of 10-11 years. We introduced the app to both classes on Zoom. This included showing students how to register, how to buy and change mascots, how to see their badges and how to use the hints and explanations in the practice mode. After this introduction, the students had a chance to play the game during the lesson, and both teachers encouraged the students to use the web app outside of school.

The International were invited to use the web app for 14 days, so slightly longer than the English users, who were invited to use it for 10 days. After this period we distributed a questionnaire to all users to receive feedback about Maths Camp. The purpose of the questionnaire was to get a deeper understanding of the value of specific features in the web app, such as the hints, explanations, feedback from the mascot and game elements. We also asked many open questions with a more general quality, for example about the visual characteristics of the web app, their opinion about the mathematics questions included in the practice mode and about their ideas for improving Maths Camp. The questions can be found in appendix 6. We chose the questionnaire format because it is an effective way of producing quantifiable data, while simultaneously allowing us to get more individual responses through freely written answers. The questions were constructed to support this. For most questions, students have to indicate their opinion on a scale going from negative to positive, on a number scale from 1 to 5 or pick between different statements. Furthermore, most questions have an optional text field where respondents can elaborate on the answer option they chose. This made the questionnaire easy to understand and convenient to fill out, while also giving respondents the opportunity to give more individualistic opinions and experiences.

4.1.2 Interview

We conducted exit interviews with both teachers of the classes involved in the user test. We conducted the interviews after receiving and analyzing the Hotjar recordings and the questionnaire feedback. This allowed us to reiterate our understanding of the improvements proposed by students, as well as gaining insight into the teacher's perception of the usefulness of Maths Camp as an educational tool. We decided to conduct the interview in a semi-structured way, since this supports the interviewee's active participation in forming the knowledge and meanings arising from the interview. This required us to create questions that act as a guideline for open communication with interviewees. During the interviews, we asked many follow-up questions and were aware of transpiring themes to support the semi-structured format. The interview guide can be found in the appendix (6).

4.2 Findings

The findings of the evaluation is divided into three sections. The first two sections are about Hotjar and database observations, where we will analyze recordings of students interacting with Maths Camp as well as the data saved in the database about each user. This reveals an overview of how students use the app and which features and pages they spend a lot of time on when playing, and it also reveals issues related to using the web app, such as navigation and errors. Then the questionnaire feedback from students is analyzed, which unveils user's individual opinions and experiences using the app in depth. Lastly the teacher interviews are analyzed and discussed.

4.2.1 Hotjar

While Hotjar captured 120 recordings, we prioritized to watch the 55 recordings, which Hotjar had categorized as having a high relevance. Recordings with a high relevance often include longer recordings that contain many user interactions such as loading a new page, clicks, scrolling, changing a field, changes in screen size, and cursor movements.

Duration

Three sessions had a duration of more than 60 minutes. 31 sessions were between 30 minutes or 60 minutes long. 29 sessions were between 10 and 30 minutes, while 58 sessions were less than 10 minutes long. The reasons for these small period interactions can be explained by the fact that Hotjar ends a recording, when the user is idle for 30 minutes or if the user moves to a new page in a new browser tab or window.

Untracked sessions

Four recordings had United Kingdom associated with the user's session, while 116 had Denmark associated. The reason for the few English recordings is unclear, but Hotjar lists a few possible technical reasons on their website such as using a browser, which Hotjar does not support, having JavaScript disabled or accessing the web app via a private/incognito browsing mode. All the known reasons why Hotjar may not track a user can be accessed here[9].

Maths Camp, MVP
Hotjar user test: 24.11.2021 - 08.12.2021
Test users: students of Rygaards International School and Halstead Preparatory School for Girls
Observed problems is classified with severity classes[12].

Problem 1: (Minor problem)
Practice page: Users click the option's text-description instead of the ratio button.
Problem 2: (Task failure)
Front page: Trouble with hovering. User doesn't have the patience to wait for the hovering of text to appear on badges. She ends up going to the badge library instead.
Problem 3: (Minor problem)
Practice page: Motivational message is not visible. Mascot are too high up on the page, when user has submitted an answer. Results in the user not seeing the motivational message unless they scroll (figure 10).

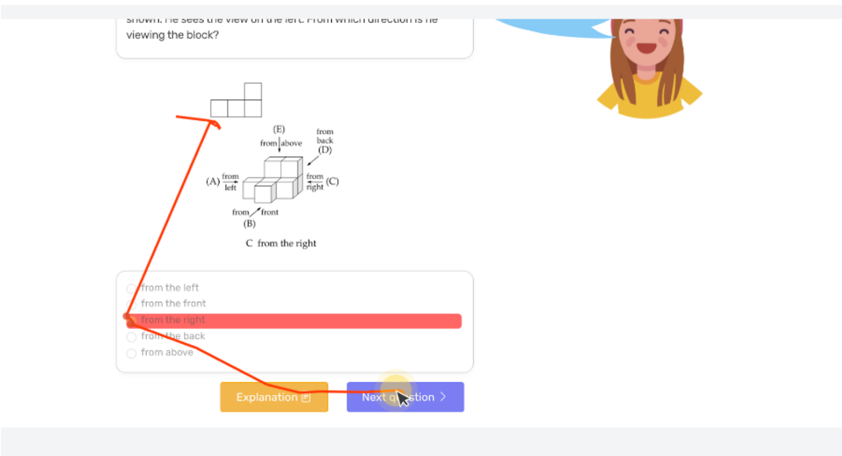

Figure 10: Motivational message is not visible

[9]https://help.hotjar.com/hc/en-us/articles/115011624047

Problem 4: (Task failure)
Practice page: Next question button is unresponsive (only a problem with a few users using Safari).
Problem 5: (Task failure)
All pages: User inputs an old URL with an expired session. User data is not fetched from the database, and no error messages are shown.
Problem 6: (Minor problem)
Practice page: Several users don't hit the radio button on the first try when picking an option.
Problem 7: (Task failure)
Practice page: User earns a badge after clicking the explanation button or after submitting a question. They go to the reward page, but when they return to the practice page, a new question has been fetched, and the explanation from the previous question disappears. This means, that the opportunity to view explanations are being limited.
Problem 8: (Minor problem)
Practice page: User clicks on the mascot image instead of the "change your mascot" button.
Problem 9: (Minor problem)
Front page: User clicks repeatedly on home button even though they are already at the front page.
Problem 10: (Minor problem)
Front page: User can't seem to find the badge library and tries to click on the badges in the sidebar. Eventually finds the "here" link.
Problem 11: (Missing functionality)
Practice page: User tries to change their answer, after submitting their answer.
Problem 12: (Missing functionality)
Front page: User clicks on the blurred badges.
Problem 13: (Missing functionality)
Practice page: Users receive points for submitting even though they haven't chosen any answer.
Problem 14: (Missing functionality)
All pages: Page goes blank.
Problem 15: (Missing functionality)
Recovery page: User gets a success message after having entered an recovery email that was not in the database.
Problem 16: (Minor problem)
Practice page: User refreshes the page to get another question.

4.2.2 Reflections

After watching several of hours of interaction with Maths Camp some patterns were prominent. Besides the usability problems presented above, we observed the following:

- **Hints were often ignored and long explanations were skipped by many users.** This was also noted in the previously conducted research, where students preferred help from a teacher as opposed to using the help and explanations provided [9]. This will be elaborated on in the teacher interview section (4.4.1).

- **Users usually needed to scroll quite a lot due to long questions including images.** This could potentially be annoying to users.
- **Users were not able to return to questions they were in the midst of solving, when they were redirected to either reward page or break page.** This happens because the web app doesn't support the functionality of saving information related to questions students are currently solving. Our hypothesis is that this annoys users as well.
- **A majority of our users did not take the 20 minutes break from solving problems, when they were directed to the break page.** It might be explained by 20 minutes being too short a practice interval, or maybe because the benefit of a break is not clear enough.
- **Users were unable to register and received the false error that the username/password was already in use.** We decided to fix this problem on the 24th of November as we found it too severe.
- **A couple of users started to focus their attention entirely on earning points instead of solving maths problems.** These users clearly only put as much time into each question as demanded to continue to advance and did not seem to care whether they answered correct or incorrect. This shows that the competition overshadowed the experience of understanding and contemplation for some users. The behavior can be seen as a result of students receiving points for all answered questions, even when they are incorrect.

4.3 Observations from database

The 48 users were created between 24th of November and 5th of December, and were also the users that answered the questionnaire. This section will examine data associated with users from the database. This gives an initial insight into the users' behaviour and interaction with Maths Camp.

4.3.1 Level

52% of the users stayed in level 1 in all four categories. Algebra was the category in which most users were left in level 1 (67%), which can be explained by the lesser amount of hints in this category compared to the others. About 30% of the users achieved level 2 in at least one of the four categories. In both of the categories, measurement and number, 14% of the users achieved level 3. 4 users (8%) achieved level 3 in algebra and only one user in geometry. It is worth pointing out that users would be reset to level 1, when they finished level 3. Unfortunately, we do not store data about the number of users who finish level 3 and are reset, which means that it is unclear whether the 52% that seemingly stayed in

level 1 in all four categories completed one or more categories. Saving data about the user's category completion would have been beneficial for future statistics provided in the teacher interface and will be elaborated on in future work (section 4.4.2).
Another thing to add, is the fact that 56% of the users played for only one day, leaving them with less time to advance.

4.3.2 Questions answered

10 users (21%) answered more than 100 questions and three users over 200 questions. 46% of the users answered more than 40 questions, while only 11 users answered less than 20 questions. Furthermore, 29% of all users answered more than 50% of their questions correct and most users (48%) answered between 30% and 40% correct. This indicates that the questions were challenging. Data concerning whether the user answered a question correctly or incorrectly the second, third of fourth time around was not saved. It could potentially be beneficial to save data about the user's interaction with each question in order to identify specific questions where the student struggle. This will be elaborated on in future work (section 4.4.2).

4.3.3 Checked explanations

All but one user checked an explanation at least once. One user checked 118 explanations, while another checked 98 explanations. 46% checked between zero and ten explanations. 19% checked between 10 and 20 explanations, while 35% checked between 20 and 118 explanations. It's possible that the few users that checked more than 50 explanations did this only to earn points. The reason why almost half of the students checked less than 10 explanation could be due to the fact that explanations were too long or they used methods that the users had not learned, which findings from the questionnaire indicate in the next section.

4.3.4 Active days

Most users (56%) played for 1 day only. 33% played for 2-3 days. The longest a user played was 7 days. The reason why more than half of the users only spend one day using Maths Camp can be due to the fact that they were not able to advance any further and simply gave up. Despite this fact it can be conducted from recordings made in Hotjar that 28% of the players spend more than 30 minutes in one session, without being inactive.

4.4 Questionnaire feedback

The questionnaire was sent out to the two teachers of the classes participating in the user test. The questionnaire was open from the 6th to the 15th of December 2021. We received all answers from respondents living in Denmark 2 days before getting responses from English students. This gave us the opportunity to compare International and English students' answers, which proved important to the analysis of the feedback.
Out of the 48 students participating, 27 answered the questionnaire. 18 of these live in

Denmark, and 9 in England (Question 1, Appendix 6). The 27 respondents overall have a good relationship with mathematics. On a scale from 1 to 5, 18 respondents rate themselves either a 4 or a 5 in mathematics skills (Question 2, Appendix 6). The same goes for their enjoyment of mathematics where 16 respondents rate themselves at a 4 or a 5 (Question 3, Appendix 6). In the before mentioned questions, respectively 7 and 6 respondents rate themselves at a 3. Thus, respectively 5 and 2 respondents rate themselves a 1 or a 2, ultimately showing that almost all students have positive attitudes towards mathematics.

Mathematics questions

The educational content of the app consisted of questions from papers provided by the teacher we collaborated with from England. The questions presented to user's in the practice component were an essential part of the app, since the goal was to create an educational app that was entertaining to use. When asked how satisfied respondents were with the exercises in practice mode, 61,5 % are either satisfied or very satisfied, 30,8 % are neutral and 7,7 % unsatisfied (Question 6, Appendix 6). These results give the impression of users generally being satisfied with the exercises.

We get a clearer picture of what students thought of the difficulty when asking respondents what they thought about the difficulty of questions. Here, 14 students report them being neither too easy nor too difficult, and 10 students report that the questions were too difficult (Question 7, Appendix 6). The difficulty is also mentioned when students are asked what they liked the least about Maths Camp (Question 9, Appendix 6). This can be due to the fact that the questions we used weren't parted into categories and levels prior to receiving them. The original plan was to use the expertise knowledge of our teacher stakeholders to define which questions belonged in which categories and levels, but this ended up failing due to planning issues. We therefore had to do this categorizing ourselves, and sorting these ended up being quite a challenge since we have little knowledge about elementary school mathematics.

Furthermore, English respondents reported being satisfied much more often than the International, and only 1 of the 10 students that noted that questions were too difficult was English. The reason for this could be due to the exercises included in Maths Camp stemming from English curriculum. It could be that International students learn different subjects, or learn them in a different order.

Many students, especially the English ones, reported liking the complexity of the educational content. Six students mention that they thought the difficulty of the questions was appropriate and challenging when asked what they liked the most about Maths Camp, "There are challenging questions to make your brain think" (Question 8, Appendix 6). When asked which features they would like to add, some students mention wanting more categories, so a higher number of mathematical subjects besides the four included. Some also suggest that they are able to pick the subject they are practicing themselves, so they only get questions within for example measurement or algebra (Question 15, 6).

Each question we wanted to define a corresponding hint, which was also not predefined. This also proved to be very demanding once expertise knowledge was ruled out as a way to define these. We had difficulties estimating what would be a good hint for different questions and finding the balance between revealing too little and too much. Nonetheless, we defined hints for 75 out of 122 questions, and had to abandon the rest due to time constraints. This also means that 47 questions had no hint, and most of these questions were in the algebra or geometry category. The least liked category, algebra, was also the category with the least amount of hints, and the most liked category, number, had the most hints (Question 18 and 19, Appendix 6). This could also be due to respondents simply not liking algebra as a subject, but it is an interesting observation.

When designing the web app, it was decided that categories would be random, and that the levels should not be visible to students since this might create unwanted competition between students. We recognized this as going against our goal of trying to provide a comfortable and safe space to learn and explore. But surprisingly many respondents suggested including information about which level they were on in each category, when asked which features they would like to add (Question 15, Appendix 6). This could be due to the levels being an important indicator of their progress, which was overlooked by focusing on the competitiveness aspect. Also, two students mention that they would like to have difficulty levels in questions. This means that some users didn't even realize that the levels existed. Including the level a student is on in a category is a valuable feature that could easily be added into the existing Maths Camp.

Lastly, a few students mention a lack of variety in questions and express a need for a larger amount of questions in all categories.

Hints and explanations

Respondents generally express having positive experiences using the hints. 54,8 % found hints useful and only two student found the hints not useful (Question 11, Appendix 6). This is supported in the freely written answers, where one respondent says: "I think its useful because on some questions i have a hard time on them and the hints give me an idea of how i can solve it". Another respondent says: "Because if you are stuck, it is like the teacher helping you online!" (Question 12, Appendix 6). So the respondents who used the hints, seem to have found the hints beneficial when solving complex problems.

The hints also proved to have some shortcomings. 19,2 % reported that they didn't understand the hints. The reason for this is explained by one students to be because the hints weren't revealing enough to actually be helpful, and another says they were too difficult to comprehend. The value of the hints is therefore very mixed, and one reason for this could be the lack of quality control. 19,2 % of respondents inform that they didn't use the hints, and many students mention the missing hints when describing why the hints weren't useful to them. Also, when students are asked what they would like to change about Maths Camp, one says they would like to always have hints on the questions. So the missing hints are definitely a problem, since they clearly have an impact on the students' user experience and their capability to solve the problems they are presented with.

Explanations were included to help users gain knowledge on how to approach problems, as well as give a step-by-step understanding of how to reach the correct answer. 65,4 % of respondents found explanations useful, and no one found the explanations not useful (Question 13, Appendix 6). A respondent writes: "It was useful because it explained the hard questions pretty well and I understood what it meant after that", and another notes: "If I got a question wrong I could see why it was wrong". This confirms that explanations are an aid to most students when learning new topics. A few students found the explanations too long and report not using them. One student explains: "I think they are a bit too long because they sometimes explain methods i haven't learnt" (Question 14, Appendix 6). So here we again can see that the difficulty of questions was too high, and this undoubtedly also translates into the explanations.

Motivation and game-based elements

The game based elements included in the web app get overwhelmingly positive feedback, and when respondents are asked what they liked the most about Maths Camp, almost all answers include the words badges and mascots: "What I like the most about maths camp is the interactivity with the badges and the mascots". Another respondent says: "... I also like that you can earn badges because it motivates us to play it more" (Question 8, Appendix 6). So the badges and the mascots was a big part of why students wanted to answer more questions and kept them entertained while learning mathematics. These elements also seem to be a big part of the motivation to keep playing the game after the user testing was done. When asking students when they will stop using Maths Camp, 29,6 % say they'll stop when they have bought all mascots, and 33,3 % says when they have collected all the badges (Question 20, Appendix 6). This supports the previous research that mentions progress as an important motivator to children, and that the attempt to include this as a natural part of the app was successful.
Respondents do request additional game based elements when asked which features they would like to add to Maths Camp. A few students propose being able to edit your mascot, for example changing their clothes or hair. Two other students suggest having special avatars that can only be earned during certain holidays, so for example a Christmas or an Easter themed mascot. Other students express wanting more badges, and one advocates for badges that are even harder to attain than the existing ones (Question 15, Appendix 6).
Lastly, a few respondents mention that they would like to change the price of the mascots, since they found them too expensive (Question 16, Appendix 6). This could be related to some students finding the questions difficult, and therefore having a hard time actually earning enough points to buy the mascots they liked. This could also be explained by something much more simple, like most students' very apparent goal to collect the mascots.

Design

When respondents are asked about their satisfaction with the overall design of Maths Camp, 60 % are satisfied, 16 % are very satisfied and 20 % are neutral. Only one person, 4 %, is unsatisfied with the design (Question 5, Appendix 6). This paints a picture of respondents generally liking the design of Maths Camp. The design elements were barely mentioned by respondents in the freely written answers, so this must neither have posed as an issue or something extraordinarily positive. Only two respondents comment that they like the colors and the buttons when indicating what they liked the most about Maths Camp (Question 8, Appendix 6). The same goes for negative feedback on the design. Here one requests a more interesting and vibrant design when asked what they would change about Maths Camp and another likes the layout the least about Maths Camp (Question 9, Appendix 6).

Errors

In order to get insight into any technical difficulties, we asked respondents if they had experienced any issues or errors while using Maths Camp. Here an overwhelming amount of respondents mention that the screen would go blank sometimes, and that they would frequently be asked to refresh the page in the practice component in order to continue using the web app (Question 17, Appendix 6). This is of course a severe problem, and it lowers the quality of the user experience, since students are being interrupted while doing problems. This can also discourage users from answering questions and achieving better mathematics skills.
It was noted that most students reporting issues with the blank screen were living in Denmark, and only one English student reported having issues with this. This is quite an odd result, and we suspect Hotjar having something to with this error. Hotjar only recorded 3 English students' sessions on Maths Camp, but almost all International students' sessions and we never experienced this glitch when testing the web app very thoroughly on our local machines. Hotjar could therefore be a possible explanation, but it is hard to say anything definitive about it.

4.4.1 Teacher interview

The teachers participating in the interviews are mathematics teachers of the classes participating in the user test. The teacher from the English school, Mrs. Tudoran, contributed to developing the concept and functional requirements, whereas the teacher from the international school located in Denmark, Mr. Greenhow, became a part of the project when we started user-testing and Maths Camp was already implemented. The transcriptions of the interviews can be found in Appendix 6 and 6.

Educational content and level progress

The idea behind Maths Camp was that it first and foremost should be an educational web app, and then the game elements were added to support a fun and entertaining learning environment that inspires confidence. One of the goals of the interviews was to get a better understanding of whether Maths Camp was successful as an educational web app for mathematics, and here the difficulty of the questions was discussed. When Mr. Greenhow was asked about his impression of the difficulty of questions, he mentions that many of his students have English as their second language, “So, often times they will struggle with understanding the questions. So it might be that they can do the math, but they can’t figure out what is being asked of them”. So, this can explain one of the reasons why many of the international students found the questions and explanations hard to understand. Mr. Greenhow also mentions the context of the questions as sometimes being the reason why questions are too complex, like using cricket or pounds as a reference in mathematical problems. Here it becomes clear that the differences in for example language and culture need to be taken into account when developing an educational app. Mr. Greenhow proposes adding explanations of mathematical terms, since that could help students expand their mathematical vocabulary. Mr. Greenhow’s students became part of the project after implementing the web app, and their lacking involvement in the development process becomes evident here.

Mrs. Tudoran on the other hand was very positive about the complexity of the questions included in practice mode, “Especially because all of them will go for 11 class exams and they do need that challenge so most of them are being used to being challenged and being able to do questions that they can’t straight away do. So, I think they are quite resilient in that way ... They don’t really give up easily as well. If a question comes up they do want to know how to do it and they will often ask me to go around and explain the questions to them”. Mrs. Tudoran explains that the 11 class exams are very important to students, since the results from these determine where they can go to high school. Some schools are very hard to get into, and this means that there is a lot of pressure on students to do well, “. . . they know if they don’t put in the work, somebody else might get in instead of them”. These 11 class exams being so important to students can partly explain why students from England didn’t report questions being too difficult in the questionnaire, since their inner motivation to learn these concepts for the upcoming exam probably made them more motivated to sit with the difficult questions. Another obvious explanation is that the questions included come from papers provided by Mrs. Tudoran, so these are of course much more likely to fit the level of the students from England.

When talking about the difficulty of questions and them being adapting to each student’s level, Mrs. Tudoran mentions that she would like there to be more questions, especially to accommodate some of the students with lower mathematical abilities, “I think there was something for everyone because the less advanced students were very excited about the badges and the fact that they could, you know, there was that opportunity there. So I think if there were enough questions for them, they could have enjoyed it even more. But even so even if the questions were not as varied for them, they still really enjoyed it”. This statement indicates that there should have been more questions that were easier to solve for students. This can be achieved by adding more levels to each category, which will make the learning curve less steep. This is also important when inspiring confidence surrounding mathematics in students since they will feel disheartened if they can't answer any of the questions as soon as they get to level 3. Overall, the lack of variety in questions was mentioned a few times during the interview, and this again confirms that the number of questions and variety of difficulty between them should be higher, and this could potentially result in students with less advanced mathematical skills enjoying learning in Maths Camp for longer.

Lastly, Mrs. Tudoran also proposes incorporating videos as explanations, instead of textual ones, "you could have a video of a teacher explaining a few questions, you know, I don't know how easy that would be, but also some harder questions, maybe they could explain how they are done". This has the potential to make the educational content even better, and could be done in many different ways. One way is an animation that explains the question in a visual manner. It could also solve the fact that some students found the explanations in textual form too long and challenging to understand.

Motivation, game elements and competitiveness

Both teachers brought up the game-base elements included into Maths Camp on their own when asked if their students enjoyed the web app, and when teachers were asked what they thought of including game elements into educational web apps, they both had a strong positive reaction. Here Mrs. Tudoran says: "But they were so excited when they got one right and they could get different points for their avatar. I think that was a great tool. They absolutely loved the mascots". Moreover, both teachers mention that they think these elements are great at motivating students to learn. In this context, Mr. Greenhow says: "And when you collect a certain number of points you get certain things. And I think that is quite effective in terms of like motivating". So, teachers share the positive attitudes towards the game-based elements with students.

Since students indicated in the questionnaire that they used other mathematical software, we wanted to know more about these. Mr. Greenhow's students use a game-based learning platform called MangaHigh, and through this platform the kids do an online mathematics challenge every year at school. Here students compete for about a month with other schools all around the world, "generally speaking, the kids spend hours and hours and hours on it, because it is like the elements of collecting points, the element of playing against each other, the element of rewards. It's a powerful motivation for sure". So here we have the additional concept of competition with other students mentioned as something that can motivate and engage. Mr. Greenhow mentions how he experiences that the kids with less positive attitudes towards mathematics benefit from the competitive concepts in between schools in MangaHigh, "Particularly for the kids who aren't feeling that enthusiastic about maths and aren't that strong with it, it's a good way of getting them more involved. And the kids that may be more into sports and stuff as well like the competitive side of it".

Mrs. Tudoran also notes that her students used an application named Mathletics where students also were able to play with students from all over the world in different online events, but she doesn't think that the educational content was of very good quality.

Adding some features that support interaction and competition between students is therefore an element that could potentially further motivate and engage students in using Maths Camp more. It would be possible to add a ranking page related to most questions answered correctly. Another idea is for students to indicate which school they go to when they register, such that schools could compete against each other in these rankings as well. Another way for students to interact with each other through the web app, is a feature where students can leave their own hints or tips on how to solve a problem for other students to then retrieve later when they have issues finding the correct solution.

Finally we asked both teachers if their students mentioned experiencing any errors when using Maths Camp. Here, only Mr. Greenhow mentioned that kids were frustrated by technical errors in the application, and this confirms that the international students were the only ones experiencing the blank screens. Again, this is difficult to explain, but like mentioned earlier, we suspect Hotjar being the culprit.

4.4.2 Evaluation Outcome & Future Work

This section sums up the findings from the above evaluation.

Game-based elements & customization

The game-based elements proved to be very effective in motivating the children to use the app. The mascots provided users with a personal character which encouraged them while solving problems. The badges and points gave them a sense of achievement and gave them the opportunity to follow their progress on different parameters. The students even asked to include more content in the existing game-based elements as well as other features. Many users wanted editable mascots, meaning they can change the hair color or accessories of an already bought mascot. They also requested special mascots available for a small amount of time during holidays.

Technical issues

Maths Camp had some technical and practical problems. Many users experienced blank screens which meant they had to refresh the page often, and others experienced not being able to click certain buttons when visiting Maths Camp through Safari. These problems have influenced the student's user experience, and can ultimately be the reason why some students choose to stop using the app.

Visible levels

Mathematical progress proved to be something the students wanted to be much more involved in than we thought. Many wanted to be able to see the level they were in, in the different categories.

Question variety & video explanations

Some users found the difficulty of the questions too high, and this can be explained through the lack of mathematical vocabulary in International students. Furthermore, the database with the mathematics questions was not complete since 47 out of 122 questions were missing hints. There could also have been more questions in each category and level, so users could experience a higher variety in questions and could progress in the game for longer. A small number of questions heighten the risk that students only put time into Maths Camp, as long as there are enough questions for them to still advance in the game. So, including more levels in each category, and then more questions for each level can make the motivation to use Maths Camp more sustainable.

In spite of this, many users were satisfied with the exercises and had positive feedback about their learning experience. Furthermore, hints kick started many students in determining where to start when encountering a complex problem, and explanations helped them understand the process of getting to the solution. It was noticed that long explanations were sometimes ignored, which according to the teacher interview, could be solved by videos of teachers explaining problems. These videos could accommodate students with lower proficiency in reading.

4.4.3 Future work

Teacher interface

For further work, the teacher interface is something that could improve Maths Camp. This could give teachers the ability of seeing statistics on their students, like which problems and categories they especially struggle with, and also allow teachers to add educational content in the form of questions specifically for their class.

Student progress

Saving additional data related to the students' progress is then needed in order to gather information for the teacher interface. One way of achieving this could be by adding a class, which stores data about the users' interaction with each question. If a user has answered a question incorrect a number of times, the question could be flagged as "unresolved" and should no longer be presented to the user. The teacher would then be able to view "unresolved" questions in the teacher interface and pay special attention to these problems in lessons.

Saving data about the question, which the student is currently solving together with a more precise tracking of already presented questions was also found to be essential. This will lead to students experiencing a higher degree of consistency in practice mode. This means that users will be able to continue to where they left off, when being redirected to other pages. This also means that user will not be presented with the same question twice in a row.

Another feature could be to decrease a user in level, if the user answers a certain number of questions incorrect in the same level. Information about a user's downgrade should also be saved in order for the teacher to decide whether a level is too difficult for the students to advance in. Finally a user's category completion should be saved in order for the teacher to know, whether more questions should be added in the category or whether the degree of difficulty should be raised.

Game-based elements

Another idea to improve Maths Camp further is to include more game elements, as these proved to be essential for the students' motivation, and kept them engaged in the web app for longer. Game elements could be daily rewards that increase the more days in a row a user logs in and different challenges that can only be completed within a certain time frame. Lastly, removing the five points students recieve when answering a question incorrect would make sure that the game elements don't distract from the educational content, like seen in some of the Hotjar recordings.

Customization

Since many students requested the feature of interface customization, this could be something to develop further on as well. Examples of this could be change of color palette, edit of mascot, and seasonal themes.

5 Conclusion

This thesis aims to investigate how to support personalized learning of math for year 6 students in elementary school. This was done by designing, implementing and evaluating an educational game-based web app called Maths Camp.

To support personal learning of math we found a number of important aspects to keep in mind. The first is high quality and quantity in educational content. This was to some extent met in this project by using content provided by a professional teacher, but the questions lacked proper division into categories and levels which ended up making it difficult for users to benefit from the app's advancement functionality.

We found that including game-based elements was extremely effective in motivating and maintaining students' attention. Besides the elements included in Maths Camp, many more could be implemented to motivate students even further. It is important to make sure that students get rewarded for completing educational content, since it otherwise can become a distraction instead of an engaging factor.

Lastly, we found that the educational content should be tailored much more to the user than we anticipated. This means that the context in which the educational content is formulated can impact how complex it is for users to decode what is actually asked of them, and can distract from even trying to solve a problem because the wording or concepts aren't within the users frame of reference. This is a strong argument in implementing the teacher interface, since teachers then can input their own content.

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