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An Engaging Worksheet: Number Ninjitzu, the Mobile Game

Abby Hull

Design & Development Project Report
Instructional Psychology & Technology, Brigham Young University

Purpose

The purpose of this project was to make a math worksheet more engaging by turning the answering of elementary math questions into a game. The game should encourage young learners to practice arithmetic more. The project takes the form of a mobile platformer game and the target audience is 1st-3rd graders.

Peter Rich is the main sponsor for this project. He came up with the original idea (“Number Ninjitzu”) several years ago and has had various people work on it, but nothing had been developed beyond some artwork and story elements. His experience working with mathematics in elementary classrooms led him to observe that worksheets could be turned into games to make assessment more engaging for young learners. Thus, his purpose with this project is to apply principles of engagement found in games to a common assessment task in order to build young students’ arithmetic fluency. *Fluency* is considered a combination of accuracy and speed in answering math questions.

The main goals of this project are:

1. first, to increase math fluency and mental math skills in 1st-3rd grade children through practice, and
2. second, to create a fun and engaging learning game that will encourage young students to enjoy arithmetic.

We hope the game will give students a more positive view of math and their math ability. We hope to further improve the game and submit Number Ninjitzu to the app stores so the public can play it more widely.

Project Needs and Constraints

I took on the role of project manager and instructional designer, directing the instructional and experience design aspects of the game. As project manager, I directed and oversaw the work done by other team members (i.e., programmers and an artist). In the following section, I provide an overview of the project. Greater detail on each of these can be found in the similarly-named appendix for each subsection.

Learner Analysis

Through reading about the psychology of learners in the 1st-3rd grader demographic and conducting observations of young learners playing educational apps (see Appendix: Learner Analysis for a detailed analysis), I was able to identify four different learner personas to target with Number Ninjitzu. The personas are:

1. The *Unengaged Learner*, who needs a way to see math as fun, could use the practice time, and is primarily motivated by external rewards.
2. *The Overachieving Learner*, who needs a challenge and a way to move beyond their grade level.
3. *The Disadvantaged Learner*, who needs a way to relearn math from earlier grades, needs lots of practice time, and is motivated by praise.
4. *The Average Learner,* who is often overlooked and needs a little encouragement.

The four learner personas were kept in mind for game design decisions. After creating the different personas and looking at my observations and interviews, I have selected some key design implications to influence the finished product.

- First, the game should provide opportunities for help, as well as clear objectives and feedback.
- Second, the game should include dramatic story elements.
- Third, the non-academic gameplay should not be difficult, as the focus should be on the math.
- Fourth, the players should receive rewards and ratings to motivate and reward gameplay.
- Finally, the game should include cool “moves” and opportunities to destroy things.

Environmental Analysis

In Number Ninjitzu, learners experience the practice of a math worksheet through a platformer mobile game. The app will be published for iOS and Android, and is playable on tablets and phones, but the main target is tablets, which are more commonly used in schools with young learners.

Research on mobile games (see Appendix: Environmental Analysis for a detailed analysis) revealed that mobile games are very familiar to US children and many parents are setting up their children to play them throughout the day. Additionally, many children have access to mobile devices in the classroom (Project Tomorrow, 2015). Children aged 2-12 spend two hours on average playing mobile games, and this age group is actually the second-highest for money spent on games and in-app purchases (Tofel, 2015). These findings reinforce the decision to create the project as a mobile game in order to reach many children.

The format of the game should encourage learners to practice more and become more fluent in math. The setup of the game should be simple and straightforward for young learners. Controls should be clearly and unambiguously marked.

Through my environmental analysis, I was able to come up with implications for the finished product.

Implications:

- The core focus should be on the math practice a worksheet offers, while making it engaging.
- Many assets have already been developed for Number Ninjitzu (artwork, story, and basic game design). The game should make judicious use of what's already been developed.
- Children are very comfortable with mobile games. Tablets will be targeted as the main platform, but the game should also work on phones.

Constraints

There are a few constraints that have been considered in developing Number Ninjitzu. Namely: the type of game being made, the game story, and the game artwork were already decided upon by the client. Many people have worked on the project over the past few years, and this project took advantage of existing assets and resources as much as possible. Another constraint was the timeline. The project was originally going to be completed by December, but this has been pushed back a semester. Finally, the cost of the project will be the hourly pay of the students involved (see Appendix: Budget and Timeline for a detailed description).

Product Description

Number Ninjitzu is a mobile game for iOS and Android (see Appendix: Design Specifications for a detailed description). The game is a platformer with a ninja theme that should appeal to girls as well as boys. First through third grade arithmetic is included in the game in order to give students the opportunity to practice their elementary math skills.

Number Ninjitzu achieves the goal of improving math *fluency* (accuracy + speed) through allowing students to practice their math skills by solving problems in each level. The game also helps students practice their mental math, by having certain levels specifically focus on mental math problems. Mental math is calculating problems using only the brain, with no other supplies or devices. Mental math is important for developing fluency because it allows the students to develop shortcuts for solving problems, thus increasing their speed, as well as their understanding of the problem.

The game achieves the goal of making math practice more engaging by providing a fun and purposeful environment for learners to practice arithmetic. The game includes interesting characters, a storyline, and motivating rewards.

We hope to achieve the goal of making the game accessible to the public by creating Number Ninjitzu in the form of a mobile game and publishing it in the app stores. Many children have access to mobile devices and they will be able to download the game from the IOS or Android store.

Game Design

The following image shows a design overview of Number Ninjitzu's gameplay, instructional principles, game narrative, and engagement elements. To understand how I brought these elements together into a single design, I provide a walkthrough followed by a more detailed explanation of each of these elements.

Gameplay • Game genre: platformer, educational • Platform: mobile • Target audience: 1st-3rd graders • Core mechanics: running, jumping, collecting (scrolls), solving/answering (math problems)	**Instructional Principles** • Fluency and automaticity • Mental math • Learning goals and standards • Just-in-time learning • Immediate feedback • Flow
Game Narrative • Visual comic-book style story • Minimal wording • Heroine supported by two young brothers • Mentor (a crane) • Inspired by Japanese folklore	**Engagement Elements** • Flexibility/choice • Rewards (outfits, new moves, unlocking more story, mini game) • Engaging story • Interesting characters • In-game currency • Ratings (stars, per level)

Walkthrough

After the player opens the app, they are able to choose their character and then start the game in the first level. Each level starts with brief learning examples that apply to the math in that level. Then an animation plays showing a crane (a mentor character in the story) dropping scrolls throughout the level. In the levels, players navigate through a landscape with platforms in order to find and pick up scrolls. These scrolls have math problems on them and numbers on the sides for players to input their answers. Players also have the ability to write on their scrolls with their finger as an added help, so they won't have to use any scratch paper. After a scroll is picked up, players attempt to solve an arithmetic problem. When they have completed all of the math scrolls in the level, players receive a level score of zero to three stars. After this, they get a report on the answers they got correct and incorrect throughout the level. Players are able to scroll through this report to see the problems they attempted with their answers, which are clearly marked as correct or incorrect. When the level is complete, a piece of the comic story is unlocked and players are able to view that piece of the story as a reward. The next level becomes permanently unlocked after playing the previous level. In addition, depending on time spent and accuracy achieved in each level, students are able to earn points to use as currency in the game store, where they can purchase new outfits. The math increases in difficulty with higher levels.

Gameplay

Number Ninjitzu is an educational platformer. In platformer games, the player controls a character that runs and jumps across platforms while moving through a landscape. However, the focus and objective of the game is finding scrolls in order to solve arithmetic problems. The platform for the game is mobile, because many children have access to mobile devices and are very familiar with them. The target audience for the game is 1st-3rd graders. We wanted to target a large group of children without having the math get too difficult and stop children from completing the game.

Instructional Principles

I did not use one specific instructional design model to design this game, but rather a few research-based principles that fit within the context of designing a mobile learning game. Namely, the instructional design of this project is informed by principles of: spaced learning, scaffolding, just-in-time learning, immediate feedback, and flow.

The math content for the game will cover 1st-3rd grade material detailed in the Common Core State Standards Initiative (Common Core State Standards for Mathematics, n.d.).

Spaced learning is an approach to learning where instead of cramming practice into one session, the practice is split up over multiple time periods, which helps learners retain information better. In Number Ninjitzu, we have 1st-3rd grade math split up over 16 levels. Instead of having completely new math for each level, 20% of the problems will be randomly taken from math in previous levels. This allows learners to constantly be reviewing old math, which will help them retain their skills better than if they practiced it all at once.

One guiding principle for Number Ninjitzu is **just-in-time learning**. Just-in-time learning makes help readily available right when a learner needs the information. This type of learning is becoming more popular today with all of the information that technology can make available in the context of when it is needed. Instead of waiting for the correct training, learners are able to get the help they need right when they need it. This principle is applied in Number Ninjitzu by providing learners with short math examples and tips right before a level starts. These examples and tips will apply to the specific math in that level and show players how to solve those types of problems. Thus, JIT methods allow us to parse instruction in smaller bits, so as not to overwhelm the learners. They are also immediately relevant to the task at hand.

These examples will also use **scaffolding**. Scaffolding refers to techniques that help students move progressively towards more advanced learning, with more help in the beginning and less help at the end. In the earlier levels, learners will see examples with animations (moving counters, highlights, etc.) to help them think through solving a problem, but as the levels increase and the math gets harder, they will receive less and less of this.

Another principle guiding Number Ninjitzu is **immediate corrective feedback**. Immediate feedback has proved to be very beneficial in improving math performance, while delayed feedback shows no benefit (Brosvic et al., 2017). This principle is applied to Number Ninjitzu by showing learners a feedback report immediately after a level is completed. This report shows all of the problems a player attempted and marks which ones they got correct and incorrect, allowing them to scroll through and review their answers. This immediate feedback is important for improving math fluency and helps learners know where they are struggling.

Another principle influencing Number Ninjitzu is the concept of **flow**, or a mental state a person is in when they are completely immersed in an activity and pay little attention to anything other than the task at hand. For learners to achieve flow, they need an equal balance of challenge and skill. If they aren't equal, learners will experience anxiety (high challenge, low skill) or boredom (low challenge, high skill). This principle is applied in Number Ninjitzu by increasing the level difficulty in a way that keeps challenge and skill in balance and encourages learners to continually reach for the next level of skill. Instead of moving too quickly through the math levels, we introduce new material gradually and with old material still present. If a new level is too difficult, learners are able to replay previous levels until they become more proficient.

Content Analysis

Students will need to understand first through third grade arithmetic in order to successfully play Number Ninjitzu. The following is a breakdown of the math (progressions) that students will need to be able to do across 1st-3rd grades.

Grade 1

- Specific strategies for adding and subtracting whole numbers within 20
- General methods for adding within 100 and subtract multiples of 10

Grade 2

- Counting in fives, tens, and multiples of hundreds, tens, and ones
- Develop fluency with addition and subtraction within 100
- Solve problems within 1000

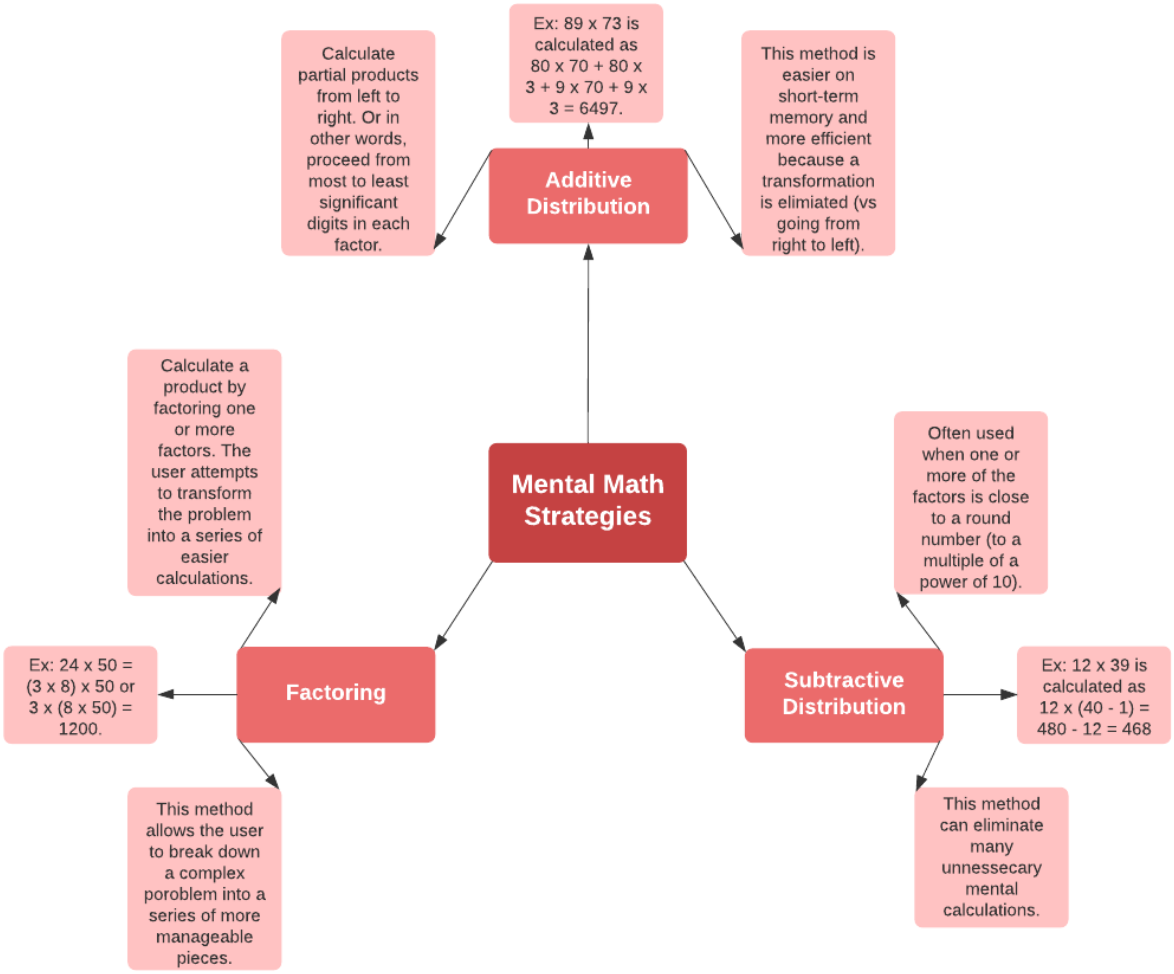
Grade 3

- Understand multiplication and division involving single-digit factors
- Multiply and divide within 100
- Learn about fractions
- Perform multi-digit arithmetic

Source: http://www.corestandards.org

Mental Math

In studying early elementary mathematics, I discovered that students need to develop mental math abilities in order to develop fluency in their arithmetic numeracy. Students will need to quickly solve math problems in order to gain the most points. Mental math involves strategies that expert learners utilize to compute arithmetic without physical tools, such as paper and pencil or calculators. The following map shows the three common mental math tricks experts use to solve elementary arithmetic problems more efficiently (Hope, 1985).



Implications

Experts often solve mental math problems in a roundabout way, such as through additive distribution, subtractive distribution, and factoring. To encourage students to utilize mental math strategies, we added just-in-time learning tips throughout the game that encourage students to think about and solve the math problems in a mental way, especially as the problems get more difficult.

Engagement Elements

Number Ninjitzu includes many research-backed elements that increase engagement. First, the game provides *flexibility* and *choice* for players, which increases intrinsic motivation (Dickey, 2007). Players are able to select one of three characters they want to play as. Although they have to unlock levels in a linear fashion, after the levels have been unlocked, they are free to play any level they choose (although harder levels will have bigger rewards, encouraging them to not just play what's easy). Additionally, players receive in-game currency in order to purchase new skins (i.e., outfits), from the many available. There are 25 available costumes for each character. Finally, players have free movement in each level and can go where they want to within the level. They

are encouraged to play quickly as the faster they solve a level, the greater their score is multiplied.

Number Ninjitzu also includes many *rewards* to help increase engagement. After completing a level, players earn in-game currency (amount depends on level difficulty, time taken, and accuracy achieved) that they can use to purchase cool new skins. After a new level is completed for the first time, players unlock a new part of the story to view. Players will receive a rating (zero to three stars) after each level attempt, which should motivate them to replay levels to get a higher rating.

Game Narrative

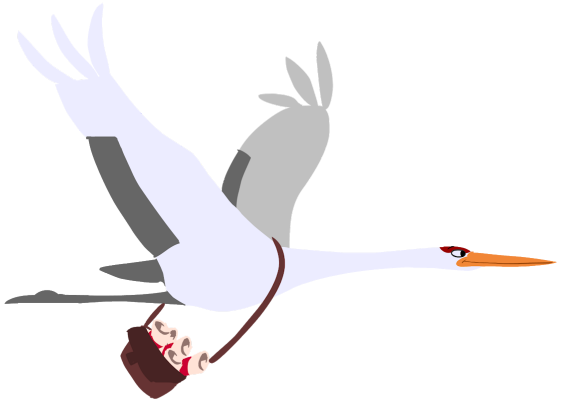
The story for Number Ninjitzu was put together by a children's book writer. She developed four main chapters for the book, but this game will only address the first chapter. She went through several iterations of the story, sharing them with her creative writing group. The writer was challenged to put anything that could be represented visually in the comic and kept the written text to a minimum in order to keep the reading level appropriate for 1st-3rd grade students. She researched Japanese folklore, which is embedded all throughout the story (implicitly and explicitly). Characters' names and objects represent key pieces of this lore. For example, the heroine's name, Kiwa, means "border," and she is the border between two worlds.

The story unfolds as players achieve a minimum passing rating (80% accuracy) for each level. Players can pass a level with one (80-89%), two (90-99%) or three (100%) stars. The first scene of the story shows a mythical creature (a “tengu”) and provides hints about the heroine’s origin. A new scene is revealed after each level is passed with a minimum passing rating. The unfolding narrative is meant to add intrigue and motivation to continue unlocking increasingly difficult levels. The narrative itself presents three main characters, aided by a messenger from the magical world (Crane), who leaves notes for the two young boys to decipher. The boys must solve math problems to unlock the notes’ messages, which ties the gameplay to the story narrative. The boys eventually meet up with the heroine and discover they are the only three people who can see the magic messenger. By deciphering messages left by the Crane, they eventually realize that they each have a magic amulet that they must take with them and that they then must deliver these to the young heroine’s pet dragon. The story ends when all three climb aboard the dragon, who takes them to the magical world.

Art Style

There are two main art styles to this app: the game art, and the story art. The game art has an upbeat, colorful art style, inspired by Mr. Peabody and Sherman (a decision made by the original illustrators), with cartoon characters who have many available costumes that learners can “purchase” with in-game currency, highly detailed backgrounds, and a black and white comic-book style comic that reveals a story as learners progress through the different levels. The cartoon style is lively and bright, to appeal to children, and the high quality art is attractive to audiences in general.

After a player has chosen a character (the heroine or one of the two brothers), a crane (the messenger from another world) introduces the level by flying across the top of the screen and dropping several scrolls for the players to find. The following image shows the crane character (the messenger from another world) preparing to drop scrolls into the level.



The following images show one of the level locations included in the game and the complete level scene. In the game, the player moves from the left side to the right side of the background. The crane drops several messages for the player to pick up and decipher (i.e. solve a math problem). The player jumps around and locates the different messages as quickly as possible.

As characters catch the crane, they are rewarded with in-game currency. They can use this to unlock several different costumes for their characters to wear. The following image shows examples of different character costumes the players can earn. There will be 25 different costumes to unlock for each character. More popular costumes (determined through learner analysis surveys) are more costly and require learners to play harder levels in order to unlock.

Similar to games like Angry Birds, players are able to unlock a level with one, two, or three stars. These correspond to 80%-89%, 90%-99% or 100% accuracy in deciphering scrolls (i.e., math problems). Once a level has been passed with at least 80% accuracy, a portion of the story will be unlocked. The following image shows an example of the comic. The art style follows traditional comic style and is in black and white. This has a dual purpose. First, it creates a distinct comic-book feel to the unfolding story and sets it apart somewhat from the gameplay. Second, using only black and white images enables the file size of the comics to be smaller, allowing for quicker load times for the in-game story. As noted in the learner analysis, young players do not want to have to wait long periods for a narrative to unfold. Thus, dialog is also kept to a minimum, using visual storytelling as much as possible.

Unity

We created this project with Unity, a cross-platform game engine that uses C# and an easy-to-use interface. As the industry-learning platform for mobile game development, we anticipate that Unity will enjoy the stability needed to maintain the game over time. This stability and popularity should also enable the client to continue to find developers to maintain the game (since there is a lot of turnover as student developers continually graduate). Also, as Unity is industry-leading, we hope to be able to find developers who know the program and find lots of support when help is needed for debugging, integrating or new ideas, or general software engineering questions.

Design Process and Evolution

Planning
During this phase, I met with Peter and Keena (the artist) to plan out the game and review existing assets. Keena had been working on art for the project for over a year, so much of that was already done when I decided to pick up the project. We decided what program we wanted to use to build the game (Unity) and started trying to hire a programmer.

We also started to plan out what learner group we wanted to target and what math concepts we wanted to cover. Although the game was primarily about improving fluency, I also decided I wanted to include examples and tips to help learners understand how to solve the math problems in each level and improve their mental math skills. I wanted to be sure they were thinking about how to solve the math problems correctly and efficiently and that they understood the concepts behind what they were doing. I also wanted them to really understand the relationships between the different numbers in a math problem.

We hired a programmer (Rory) who had Unity experience and he began experimenting with building out a level (the game would eventually have 16 levels). He was able to incorporate a lot of the art and animations into the game and he created a basic, functional level. Keena graduated and was able to recommend another artist named Abby, who began working on interface design and additional art that we still needed (e.g., much of the game and interface elements). I worked with them to build the game and also began fleshing out the instructional side of the game.

First Prototype Phase
Rory graduated in August and hadn't finished as much of the game as I had hoped. I was worried about finishing by December like I had originally planned, and so we decided to hire two new programmers to finish the game. We held a lot of interviews and ended up hiring Garett and Brady, who both had a good amount of experience with Unity. Brady primarily worked on building the levels in the game and Garett worked on the UI elements. Abby continued to work on art and ended up having to do a lot of animation work in a program called Spine, which allowed her to create a skeletal frame for the characters which she could then animate. I managed the team and the game development. We met weekly as a whole team and I often met in-between our weekly meetings with individual team members to consult on specific game decisions and direction. During this period, I also researched common core math for 1st through 3rd grades in order to decide what math problems should be presented in each level. I decided to create just-in-time math examples that would teach learners how to do the math prior to playing a specific level. . We were hoping to have a prototype people could download to their devices to test over Christmas break, but the programmers weren't able to get this working, so I was only able to test on my phone with family over break. I was able to find bugs and things that were confusing to players, such as how to navigate and understand the pre-level examples and how to navigate through the interface.

Second Prototype Phase
For our final prototype, we built out 14 levels and put in all of the UI elements. We then tested the game on 14 children over 3 days to gauge the extent to which the game met its intended goals. While there are still additional minor functionalities that we would like to build in, the minimum

viable product has been built. Most of the art is finished and all of the instructional elements have been added.

Product Implementation

For Number Ninjitzu to be tested, we needed to get the game onto phones and tablets (see Appendix: Implementation Instruments for a detailed plan). We did this through an .apk (android package) for Android devices and testers had to download and install the files to their devices. Unfortunately, there were problems building the game to iOS devices using BYU's developer account, and we weren't able to find a way to deliver the game to Apple devices remotely for the test.

For Number Ninjitzu to be widely implemented, we will need to publish the app on the iOS and Android stores so anyone can download the game. The game should work on all phones with the latest operating system.

I piloted our product by finding participants in 1st-3rd grade who had access to a smartphone or tablet, in order to play Number Ninjitzu. They needed to understand basic mobile game technology in order to operate the app. They also needed to have the ability to solve math problems starting at a first grade level. I checked with their parents beforehand to make sure they had the required technology and ability to test.

The parents were provided with instructions on how to download the app, how often the children would need to play, and what questions to ask them after they played.

Assessment and Evaluation

Criteria

Peter Rich is the main stakeholder involved in this project. He is interested in whether the game will increase math fluency and engagement. The IPT Department is also a stakeholder in the project, as they are funding it. They expect the game to be used for educational purposes.

The two main goals of this project are to increase early elementary students' math fluency and to do so in an engaging way. These two outcomes (fluency and engagement) guided the following assessment and evaluation.

Procedures

Assessment
For Number Ninjitzu, assessment (see Appendix: Assessment Reports and Instruments for a detailed plan) is built into the game by default, as it's the main focus of gameplay. Because of this, we were able to collect assessment data through the game itself. The data was collected anonymously to be compliant with FERPA. This data is collected in the form of learning analytics and will be used to improve the game incrementally, though those improvements are likely beyond the scope of this project.

Some examples of data we attempted to pull are:

- How long do players spend on the game total?
- How long do players spend on the game per session?
- How long do players spend on each level?
- How many times do players replay each level?
- How do players improve in accuracy the longer they play?
- How do players improve in time the longer they play?
- What questions are the easiest to answer and what questions are most difficult to answer for players (based on time and accuracy)?

Additional assessments have been used for the purpose of evaluating the two main goals of the project and are described in the sections below.

Formative Evaluation
Formative evaluation took place throughout the game development process (see Appendix: Evaluation Instruments for a detailed plan). In weekly team meetings, we discussed artwork, user experience, motivating elements, instructional progression and support, and overall gameplay. Additionally, we held informal playtests to see if the game was functioning well and to see what players liked and didn't like.

Evaluation Questions
The main evaluation questions I asked at each stage included:

- Is the game focusing on grades 1-3 math?
- Will the game help learners improve their math fluency?
- Is the game engaging?
- Does the game help students develop a more positive view of math and their math ability?

Summative Evaluation

For summative evaluation, I looked at the data collected through the following quantitative and qualitative assessments and reviewed our learning analytics data to evaluate whether the project satisfied our learning goals. I decided the product would be considered successful if learners increased in math fluency after playing the game, if learners reported largely positive views of the game, and if learners were motivated to play the game often.

Criteria 1: Math Fluency

In addition to collecting learning analytics, I assessed students' knowledge through a simple pre/post experience. To do this, I piloted the game with 14 young learners. This helped me evaluate whether learners achieved the goal of improved math fluency. The children chosen to test the game were given a worksheet prior to playing and were timed to see how many problems they could complete within a given time limit. The worksheet given was matched with their grade level and included all relevant arithmetic (e.g., the third grade worksheet included addition, subtraction, multiplication, and division). Then, the children were given the opportunity to play the game for three days. After trying out the game, students were given the same type of worksheet and timed in the same way to see if their math fluency improved. We looked at the scores to see if there was significant improvement in math fluency before and after playing the game. This second means of assessment (apart from collecting data straight from the game) also helped us see if the learning from the game translates well to traditional tests, like a physical worksheet.

Criteria 2: Learner Engagement

I used observations and interviews to see what players liked and didn't like about the game. I analyzed their feedback together with learner analytics to evaluate what motivates the learners to play the game more and what needs improvement. I discussed my findings with the team in weekly meetings and got their opinions on how to address the needed changes. We also got student feedback after administering the post-test to ask students what parts of the game engaged them the most, how the game compares to other games they've played, if they're likely to keep playing the game, if they thought the game helped their math skills, and if the game made them like math more.

Qualitative data from the observations and interviews was reviewed, with the purpose of looking for common themes.

Evidence

We gathered analytics through Unity Analytics (see Appendix: Assessment Reports and Instruments for a detailed description of the data collected). We enabled different custom parameters to try and track players as much as possible, such as how much players played the game each day, what their average scores were, and what level difficulty they were playing.

Usage analytics revealed:

1. that testers played an average of 24 min, 27.5 min, and 27.33 min a day over a three-day test. Overall, they played an average of 26.28 min a day, which matches up pretty well with their self-reported average of 25.12 min;
2. players' average level scores over the three-day test were 13.46, 13.79, and 12.44 respectively; and
3. the level difficulty they were playing at on average each day was 2.63, 1.86, and 5.81 respectively.

Learners were only required to play 15 minutes a day, so this indicates they were motivated to play longer than required. Their level scores increase and then decrease, but seem to correspond with the level difficulty they were playing at. The average level difficulty decreased for the second day and then increased significantly for the third.

We were also able to pull data on which costumes were purchased. No single costume was purchased more than the others, and most of those purchased were the cheapest costumes, possibly because the test only lasted three days and players may not have had enough time to earn enough coins for the more expensive costumes.

Success Criteria

In the following section, we review indicators intended to measure the extent to which the app met project goals. These refer specifically to learner achievement and learner engagement.

Criteria 1: Math Fluency

Unity analytics showed level scores increasing a bit on the second day and then decreasing on the third day. This is affected by what levels users played (difficulty of the level and different levels having different top scores), so more testing and more detailed analytics would be needed to see if their level scores improved the more they played the game. This also seems to correspond with the average level difficulty they were playing at each day (when difficulty increases, scores decrease).

However, traditional academic measures revealed clearer outcomes. The pre/post worksheet test showed an average improvement of 23.72% (problems completed) and 24.55% (problems correct) on the worksheet taken after playing the game for three days versus the worksheet taken before playing. Three children didn't complete enough for the test and were taken out of the data.

Criteria 2: Learner Engagement

Players self-reported how much time they played each day and it came out to 22 min, 21.91 min, and 28.64 respectively, with an average time played of 25.12 min a day. This was just slightly under the usage analytics we collected automatically.

The following are takeaways from the feedback survey I administered after participants tested the game for three days. I format the takeaways according to the questions I asked.

Did you see any bugs or problems with the game?
There were some really good bugs reported, mostly to do with the game freezing at a couple places and also one math issue, where the answer was five numbers, but they could only type in four. Players also complained about the comic being hard to read, but this is because our artist hasn't finished all of the comics and some of them are still sketches with handwriting.

We intend to go through and resolve all of the bugs, as well as finish up the art for the final version.

What did you like about the game?
Things players liked about the game included being able to choose their characters, earning coins and buying costumes in the shop, the cool art in the game, collecting scrolls, the adventure and storyline, the comics, the challenge of getting stars, being able to run and jump, the flips, being able to draw on the scrolls, and the math problems. These are illustrated by their following qualitative responses:

- "I just got addicted. I couldn't help it. It was just like I need to play more."
- "I really like the store and the different outfits and I liked the times tables and division. It's cool to have an adventure and collect scrolls and it's a fun challenge to try and get three stars and I loved the comic a lot. I loved the flips."
- "It has a storyline and you can actually make progress and earn coins. I like the characters and the costumes and the art."
- "It was so fun because it was like a video game."
- "I like the shop and all the cool things that you can get. And I liked the scrolls, they look really old and it's cool. I like how the crane flies and drops the scrolls."
- "Being able to choose characters and that you can get coins. Nick was my favorite character."
- "I liked the math problems."
- "The practice before the levels makes solving the problems so much easier."

We were pleased with this feedback. The things we hoped would entertain and motivate players are the same things they mentioned. I was glad to hear that the pre-level practice (i.e., help with knowing how to do the problems coming up in the level and explaining the mental math strategies) was helpful, indicating that the just-in-time instruction was a useful strategy for educating while maintaining engagement.

What didn't you like about the game?
There were also a number of things to improve about the game. Most of the feedback had to do with game bugs. However, players also mentioned the math being too hard and the levels being too similar. Additionally, some kids didn't find the costumes or the comics and another was frustrated with the characters moving too slow (they run if you double tap, which is in the tutorial but only briefly). Another was confused about how to get on the roof.

This feedback tells me that we need to make the interface clearer and also explain more clearly how to play the game or make things more intuitive.

- “The levels are too similar.”
- “The comics weren't super accessible.”
- “On the first level it was really confusing on how to get into the roof “

What would you add or remove to make the game better?

Things players would want to add to the game include flying (this is in one of the later levels), fighting monsters, more big jumps, a swimming level, more flips and moves, more characters, and different level scenery.

- “Add power ups or different scenery/backgrounds.”
- “You should have more flips and moves as you become a ninja.”
- The only things they said to remove are the math and the climbing, because it was difficult.

This is great feedback and I definitely think we can add more fun and surprising things to the final version of the game. We also need to work on making the climbing move more intuitive.

What are your top three favorite costumes?
There weren’t any repeat costumes in the feedback, but I think if they would have played longer and unlocked the more expensive and “cooler” costumes (they can’t see them unless they purchase them) then some favorites would emerge.

Is this game more or less fun than other math games you have played? How is it different from other math games you’ve played?
Eight said it was more fun, two said it was the same, and one said it was less fun than one game they’ve played.

- “Way funner by a long shot.”
- “It's fun (it's equal fun to other math games).”

Would you keep playing this game on your own?
Out of the children who took the survey, nine said yes, one said probably, and one said maybe.

- “Yes (she literally asked if she was able to keep playing).”
- “Yes I already want to.”

Do you think playing the game helped your math skills?
Five said yes, five said no, and one said kind of.

Did the game make you like math more?
Eight said yes, three said no. One child who “hates math,” said “Absolutely not!” but she did enjoy the game. A few kids mentioned that they already really like math.

Outcomes

Again, the two main goals of this project were to increase early elementary students' math fluency and to do so in an engaging way.

The initial evaluation suggests that these goals are being positively met after only three days of playing the game. However, these are limited by the sample size and method. More testing and more specific analytics with a larger, more diverse, group are needed in order to see if Number Ninjitzu reliably improves fluency and to see if this fluency is retained over time.

Evaluative feedback leads me to conclude that this project is a success in terms of engagement. The testers played on average almost double the amount of time they were required to play, which means they enjoyed playing the game and were motivated to keep playing it. The majority of testers really liked the game and said they would keep playing it on their own. The elements we hoped would be fun and engage players such as buying costumes, earning stars and comics, etc., were all mentioned in the things they liked about the game. Most of the testers also said this game was more fun than other math games they've played. I am excited to take their feedback and continue to improve the game until it is completely polished and ready to publish to the app stores so more kids can play it.

Design Knowledge and Critique

Strengths and Weaknesses

One of the major challenges of this project for me was having to hire student workers, because they are still learning and aren't experts in Unity programming (BYU coursework doesn't teach Unity specifically). They also are busy with school and can't work a guaranteed amount of hours. This weakness could have been minimized by hiring non-student employees who have more expertise in Unity and other game design essentials like animation, and who are able to commit to a specific work schedule and have the job be their focus.

Another weakness was not being able to test out the project as much as I'd hoped, both due to the pandemic and a lack of testable prototypes. This was in part due to a misunderstanding of the limitations placed on a university program account for the Apple App store, which doesn't allow distribution of the app to testers. Consequently, the team struggled to deliver the game to testers remotely, and due to the pandemic, I couldn't really go test out in person. Because of this, I have only been able to do small tests in person with testers in my immediate social circles. Fortunately, for our final prototype, we are able to let testers download the game remotely on Android devices. In an ideal situation, I would have liked to go observe students playing the game in a classroom setting.

One strength of the project is that the art assets were almost all completed when I was brought onto the project. This made it a lot easier to begin and not be held back by not having assets, because developing art assets for games takes a long time. Designers could take advantage of this strength by having a clear plan for a project and all of the needed assets ready before officially hiring people to start the project, so less time is wasted waiting for assets to be created.

Another strength of the project was having Peter Rich as a mentor. He has so much educational game knowledge and experience, and it has been a great experience to get his advice and feedback throughout development. He also was the one who originally came up with the idea for Number Ninjitzu and cares a lot about its success.

Project Improvement

This project could be greatly improved given greater time and resources. We have had so many good ideas that can't be implemented because the programming and art sides are too slow. I think having people on your team who really understand the scope of the project would have really helped us decide what to focus on and what to leave on the cutting table. However, the team isn't very experienced with game development and couldn't accurately predict how long things would take to build. As a project manager, it can be difficult to manage a project and set timelines when those creating the product don't have a good sense of how long it takes to complete their tasks, or are unskilled in these tasks to begin with.

I have put a lot of work into this project and I really believe Number Ninjitzu will be able to help kids practice math more and have fun doing it. After graduating, I am going to continue to supervise production until the game is really polished and has been published to the app stores. I really want to see the game become widely available.

Reflection

Before beginning a project like this, I would tell designers to talk to experts who truly know how long a game like this would take to create. I would tell them to hire people who are realistic about what they can do and how quickly, and who are able to meet deadlines. I wish I would have decided at the beginning what elements of the game were most essential and should be focused on, instead of being distracted by fun things that seem simple, but take too long to implement, such as adding special moves, which ended up taking a ton of time and causing a lot of bugs.

I have learned a lot about design during this process. I think the main thing I've learned is that the design process is a lot different and more difficult when managing a team and trying to juggle all of the different pieces of a project. When managing a real project with a real team, things don't fit as nicely into specific steps as when I'm working by myself in class. There are many overlapping parts and people with different ideas of how to do things. However, it's very rewarding to work as a team and see more ideas and perspectives than if I was working on my own.

Along with this, I have learned a lot about what it takes to manage a team. I have learned that I need to be more firm in my approach as a manager. Initially, I worried about coming off rude or demanding, and I was definitely too relaxed with my management style. If someone said they would do something by a certain date I would believe them, and if they didn't get their work in on time, I had no consequences. I have learned that expectations need to be set up early and followed up on readily. Since I was too easy going from the beginning, some team members didn't take the job very seriously and didn't meet their deadlines like I'd hoped.

As the project has come to an end, I have tried to take management more seriously and talk to my team differently. I had to sit down with a team member and really talk about my frustrations and expectations for the future. I was really worried about seeming mean, but the discussion really helped both of us and the team member's work has been a lot better since. Although managing a team of student employees is different than normal work, I think respecting each other through words and actions is really important. Next time I manage a group, I want to create a better balance between being a friend and being a boss. I want to be more clear about deadlines and expectations being serious.

Lessons Learned

Managing this project has taught me a lot, and I've definitely grown through the experience. I've learned to focus on the essentials of the project first, instead of getting distracted by fun but low priority things. After working with five different student employees, I've realized it's important to be a manager first and a friend second in order to be most effective and productive. Finally, after experiencing many technical issues that delayed my project, I believe that it's best to choose a project you can finish on your own in a worst-case situation. I elaborate on each of these themes in greater depth below.

Focus on the essentials and then move to extra things if you have time. As we discussed as a team what we wanted in the game, we always came up with many different fun ideas in meetings. The programmers and artists would experiment with the fun elements we wanted to try out, taking up a lot of their time. For example, we wanted to implement a lot of fun special moves in each level and we also wanted players to use the special moves to get hard-to-reach scrolls. However, the programmers spent so much time figuring out what special moves we could use for each level and implementing them. The moves also caused a lot of bugs that then had to be

fixed, and some weren't fully fixed for the test, causing the users frustration. The moves were cool, but added a layer of complexity that wasn't necessary and they also took time away from essential programming things. Because of this and lack of correct focus in other areas, the project test had to be delayed by a semester. The programmers went down to the wire trying to add last minute important things, while we had wasted weeks on things that weren't as important. The game was crashing constantly right before the test and so we had to delay it. Our artist also had spent a lot of time testing out different interface designs early on and wasn't able to finish all of the comic art before the test, which was frustrating. My advice is to be careful of getting excited about all of the small fun details in a project. Although adding cool extra things is great, they shouldn't be worried about before the essentials are completed. Assigning priorities to tasks is helpful, which we started doing near the end, but it would have been helpful from the beginning. It's nice to have good ideas and keep a record of them, but shift less important ideas to the bottom of the list, instead of trying out every new thing right away. Keeping important things until the last minute is extremely stressful and even caused my schooling to last a lot longer than I'd hoped.

Be a manager first and a friend second. Working with student employees can be difficult right from the start, since their work hours vary and school will always come first, especially during midterms and finals. They also may not be good at estimating how much time they'll be able to work while managing their homework load or how long tasks will take them, since they haven't done these jobs in a real working situation before. My management skills have improved immensely since I started the project, and I wish I had been more effective from the beginning. I started off treating my team like friends and being extremely flexible with them. They weren't giving me very realistic timeframes for when they could complete things and I was okay with them taking a lot longer than expected or needed. I didn't keep track of their hours or when they worked at all. This flexibility isn't very realistic when compared to a real working situation. Because I was so nice and hands off with my team, they didn't feel very stressed about finishing up their tasks. This caused things to take much longer than expected and my graduation was delayed multiple times. My team would assure me things would be done quickly and then they would take way longer, which was very frustrating for me. Eventually, I had to get a lot firmer in my management style and hold them to their deadlines. I had the most trouble with one of my artists, who would constantly assure me during meetings that things would be completed quickly and that she would deliver them on a specific day and time. She would act very optimistic in person, but then would never respond to me through text or email and wouldn't send over art at the times she had said she would. This got very irritating, because the programmers were waiting on very simple changes for weeks or months, which put them more behind. Anytime we discussed a potential art change, I didn't even want to bother putting it on her list, because she already had so many things and I knew it wouldn't get done. It got to the point where I had to figure out a lot of the art changes myself, even though I'm not experienced. Finally, I sat down with her a couple weeks before our test deadline and had a serious discussion with her. She acknowledged that she hadn't been doing the work expected of her and said she would do better in the future. Things got a bit better for a couple weeks, but the project ended up getting delayed when we weren't ready for our test. She quickly went back to normal and was making little progress again. I met with Peter about this issue and he decided we should both sit down and talk with her. She told us about some personal difficulties she'd been having and apologized for her tendencies to be really optimistic about everything. I told her I was happy to be more flexible with her personal issues, but that I needed honesty instead of fake assurances about when she'd be able to do stuff. We also decided to set up a check-in system, where she would

update a document each day with how many hours she'd worked and what she'd been working on and I would check in with her twice a week. Things haven't been perfect, but definitely better with the added accountability, which I wish I had done from the start. I think recognizing that employees have different personalities and needs is important when figuring out how to keep them accountable and how much supervision they're going to need. It was also helpful to sit down and actually ask her what structure she needed to be accountable for her work. If I was starting this project from the beginning, I would be a more firm manager and also begin with an accountability structure in place, where I would be able to know how much they were working and what they were working on at all times. I would also be more serious about holding them to their deadlines and having clear tasks and priorities. I always want to treat anyone I manage with respect, but they also need to understand that they are doing a real job and that there are expectations in place. Luckily, I have learned a lot from this experience and will be a different kind of manager the next time I get the chance.

Choose a project that you can finish on your own if needed. Although this project was really fun and unique, it required a lot of technical skills that I don't have. Because of this, I had to rely a lot on other people and when they didn't finish their side of things, my graduation got pushed back. I put in a lot of work to the project, but it was frustrating when others on my team were behind me and there was nothing I could do to speed things along personally. The last semester on my project, I was mostly just supervising and waiting for the programming and art sides to catch up. The game didn't get as polished as I would have liked, but it was completed enough to test. It was a great experience to work with a team and be in a management position, but my advice would be to pick a project that you can finish on your own in a worst-case scenario, even if it would be a lot of work for you. It was a really hard experience to have little control over my own graduation and to have to delay things just because other people on my team weren't finished with their part.

Appendix

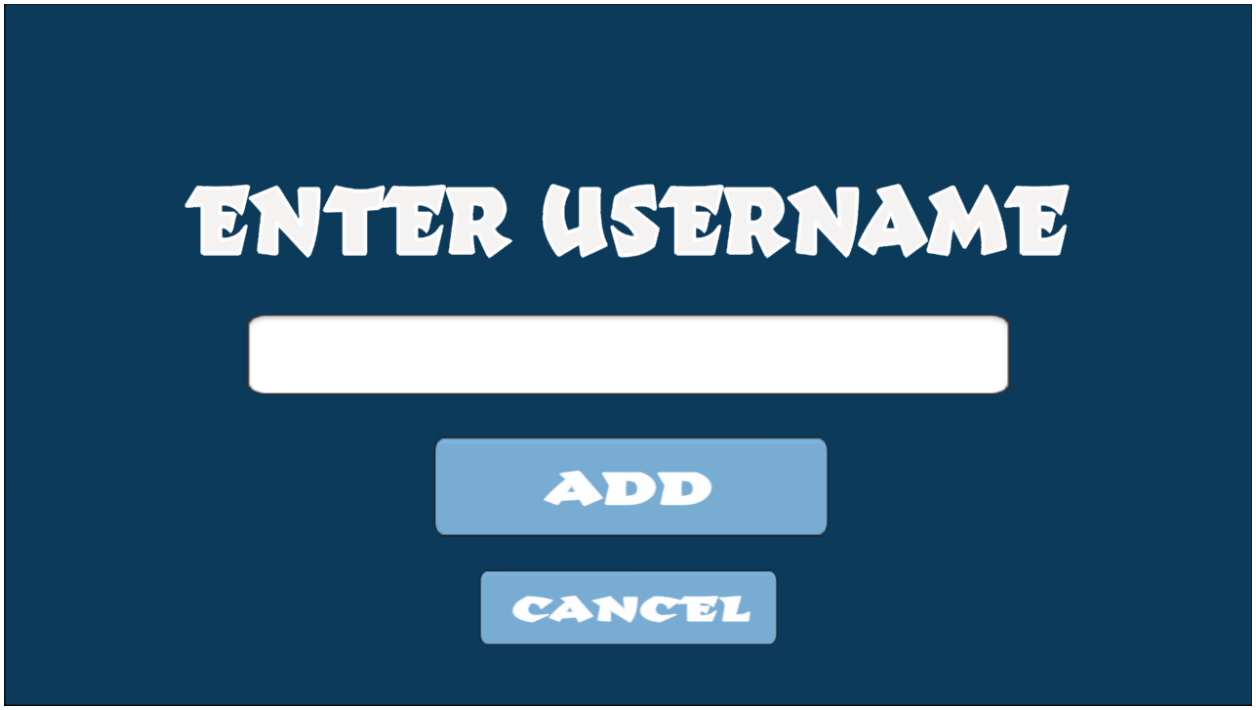
Actual Product

.apk file (Android package)
https://drive.google.com/file/d/1MxZZTy022NXNd6jS_Yuodmj98D1oCEaK/view?usp=sharing

Product Walkthrough

The following link provides a recorded walk-through of a player using the game in its current iteration (https://youtu.be/tnvvDNoiLu4). In addition, I provide a guided walk-through using screenshots with the following images and narrative.

Creating a User
When a player first enters the game, they need to create a user. Because we expect teachers to be able to use Number Ninjitzu with a whole class of users, we did not place any artificial technical limits on the number of users that could be created per device.



Main menu

Once a user has been created, the player is taken to the main menu, where they are given a choice of playing the game (start), choosing a different user (user), changing the settings (set up) or quitting.

Levels menu

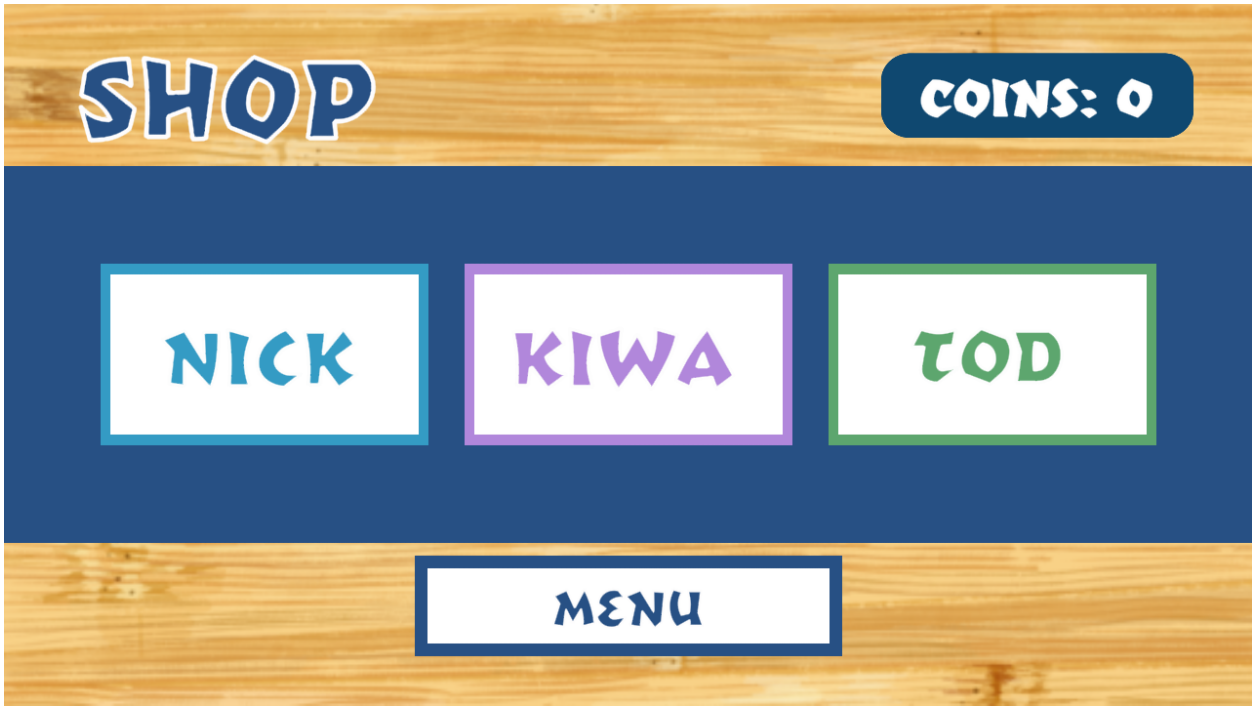
If a player chooses, “start,” they are taken to a screen that shows the different levels. Locked levels are “grayed out” and must be unlocked by earning at least one star on the prior level (in the below picture, all levels are unlocked).

Avatar menu

In the avatar menu, a player may choose which character they want to play as.

Shop menu

In the shop, players can purchase and equip new costumes for their characters. They must earn in-game currency in order to purchase a costume. They can earn currency by playing the different levels.



Shop - Kiwa

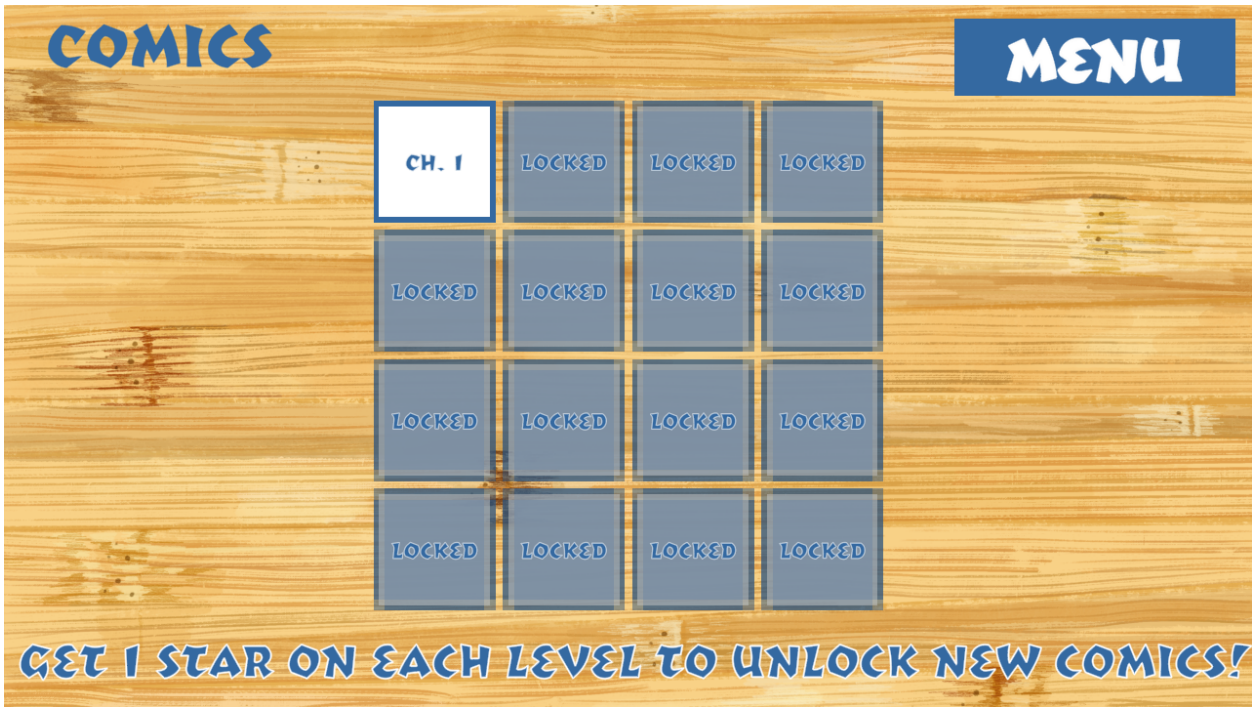
The shop has many different costume options for each character.

Kiwa costume

The following picture is an example of a costume that can be purchased. After purchasing a costume, players can equip it and it will show up in the next level they play.

Comic menu

Players are able to come to this screen to read the comics they've unlocked. The comic for a level is unlocked if the player earns at least one star on that level. Locked comics are grayed out as shown below.

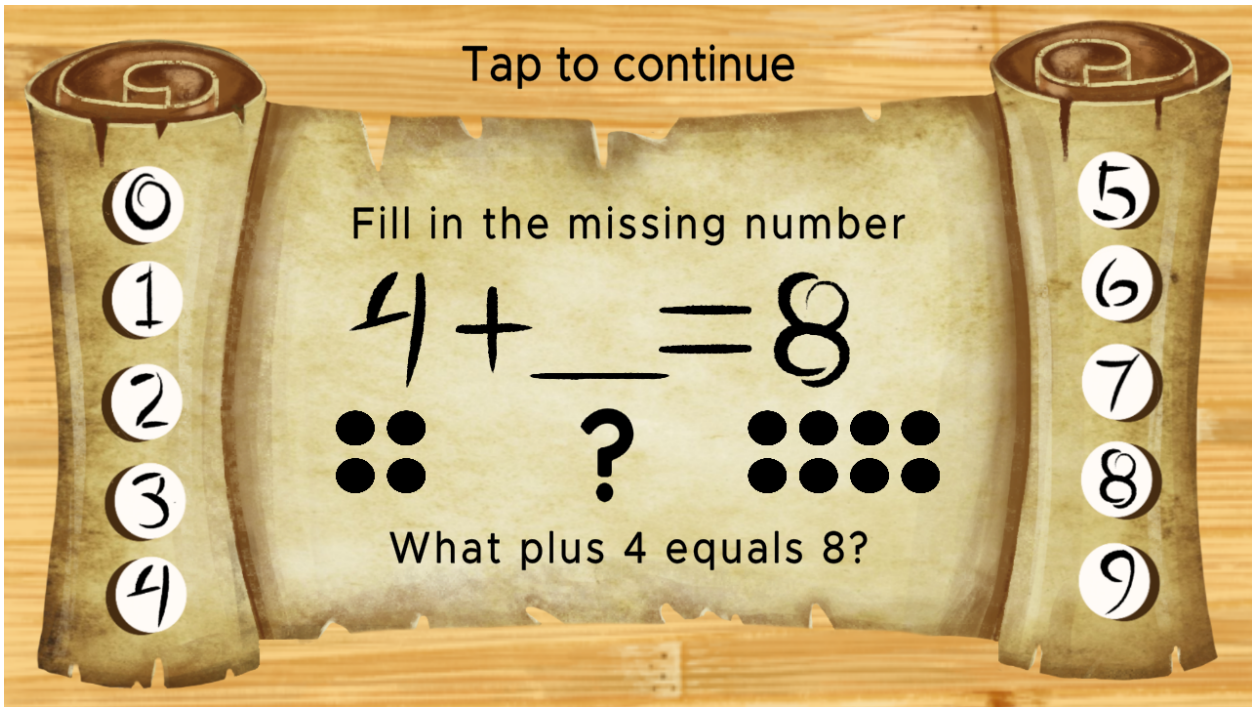


Comic - Chapter 1

The following is the first page for the chapter one comic. Players can hit the arrows to scroll through and read the comic.

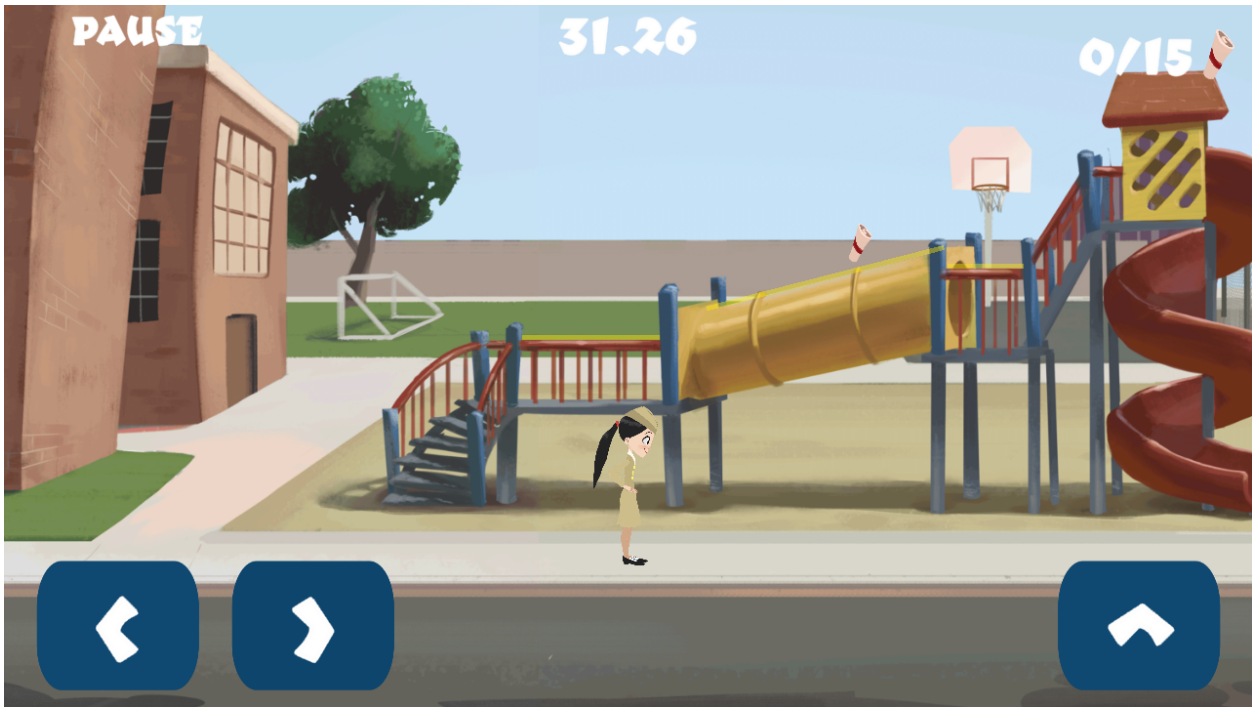
Pre-level example

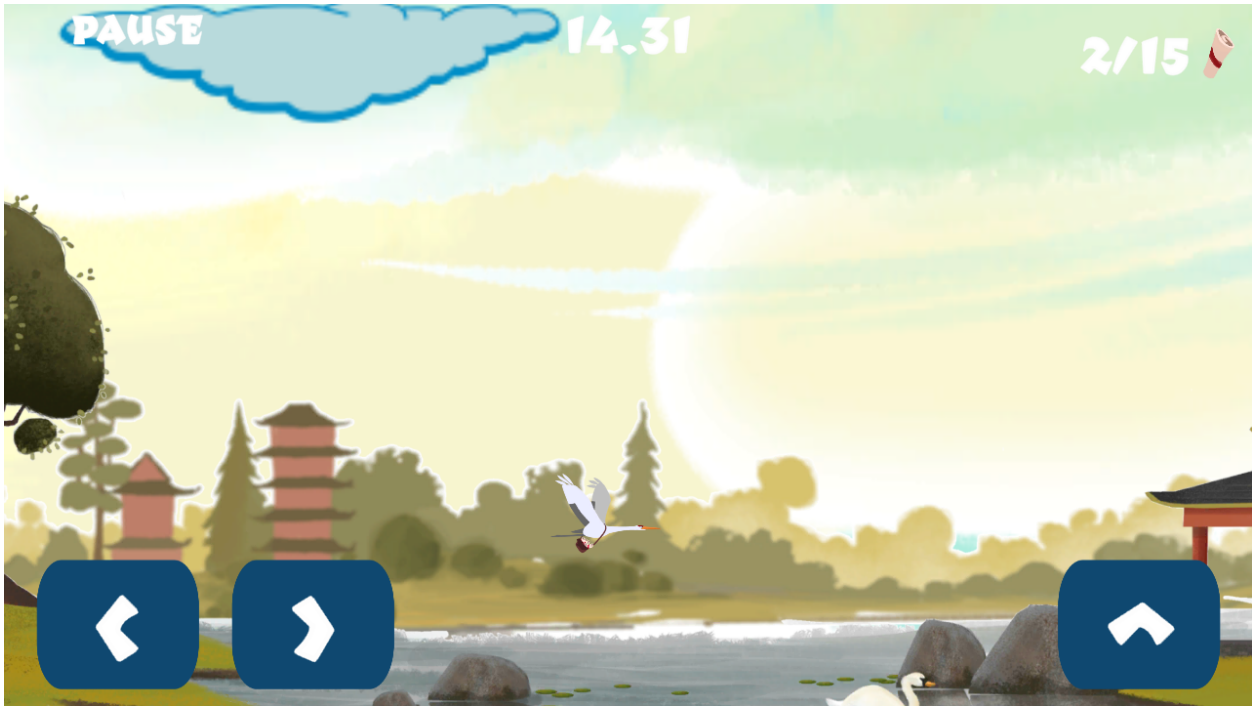
The following shows one of the pre-level help screens for level one. As the players start each level, they will see examples of the math in that level and be shown how to solve the problems.



Levels

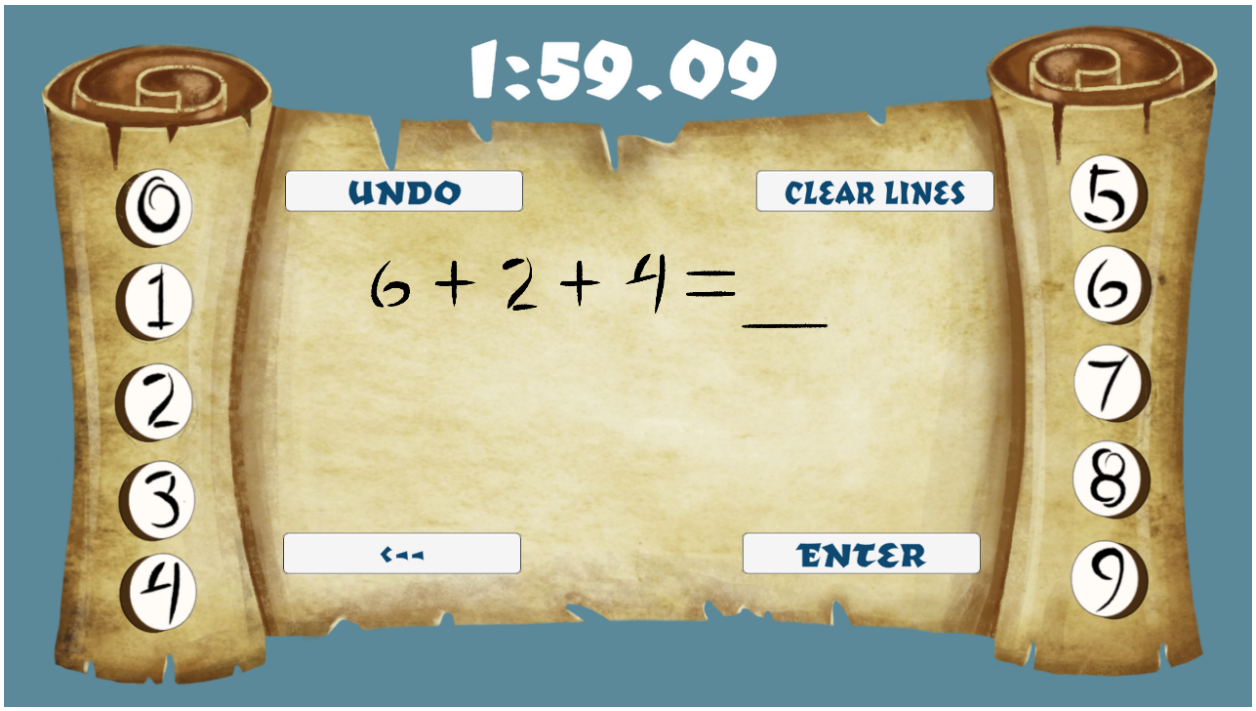
When the players enter a level, their objective is to find all of the scrolls in the level and solve the problems on them. They can walk or run using the left and right buttons and jump using the up button. They can see how many scrolls they have left to find and how much time they've taken. The following three images show different levels. The third image shows an extra fun level, where they get to play as the crane and fly around.





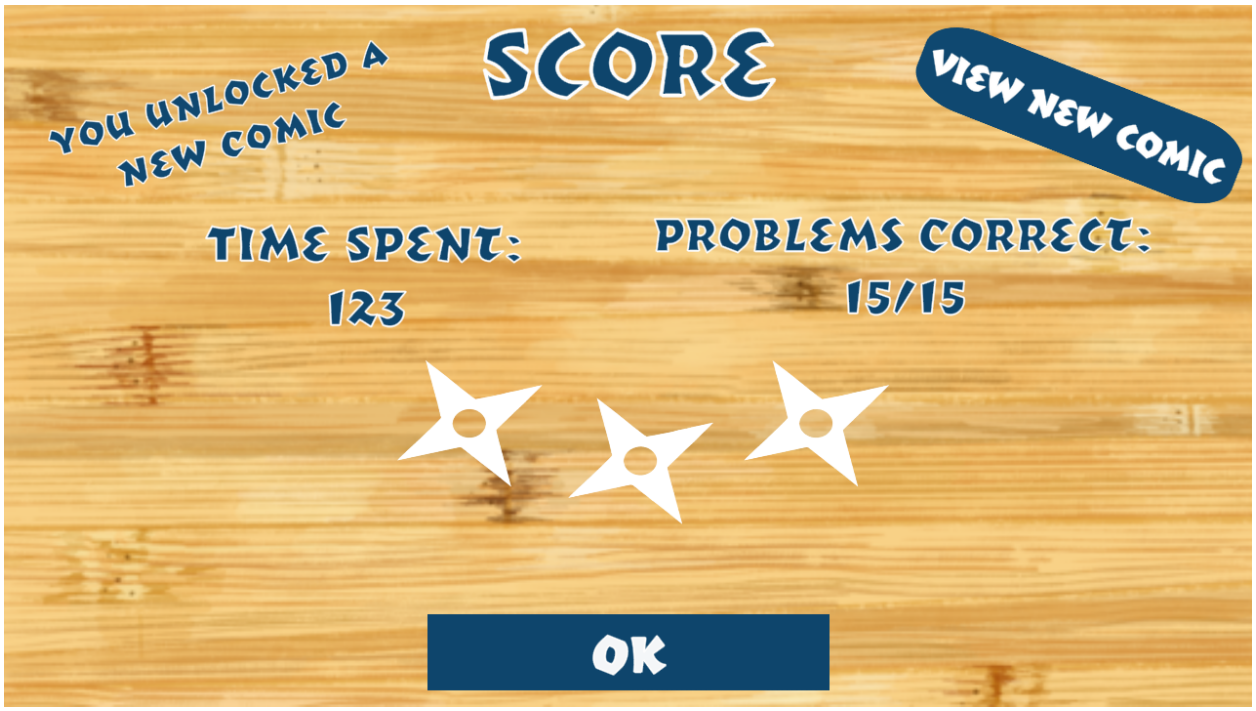
Scroll math

The following image shows an example of a problem the player will receive after they land on/pick up a scroll in the level. After answering the problem, they will go back to the level background.



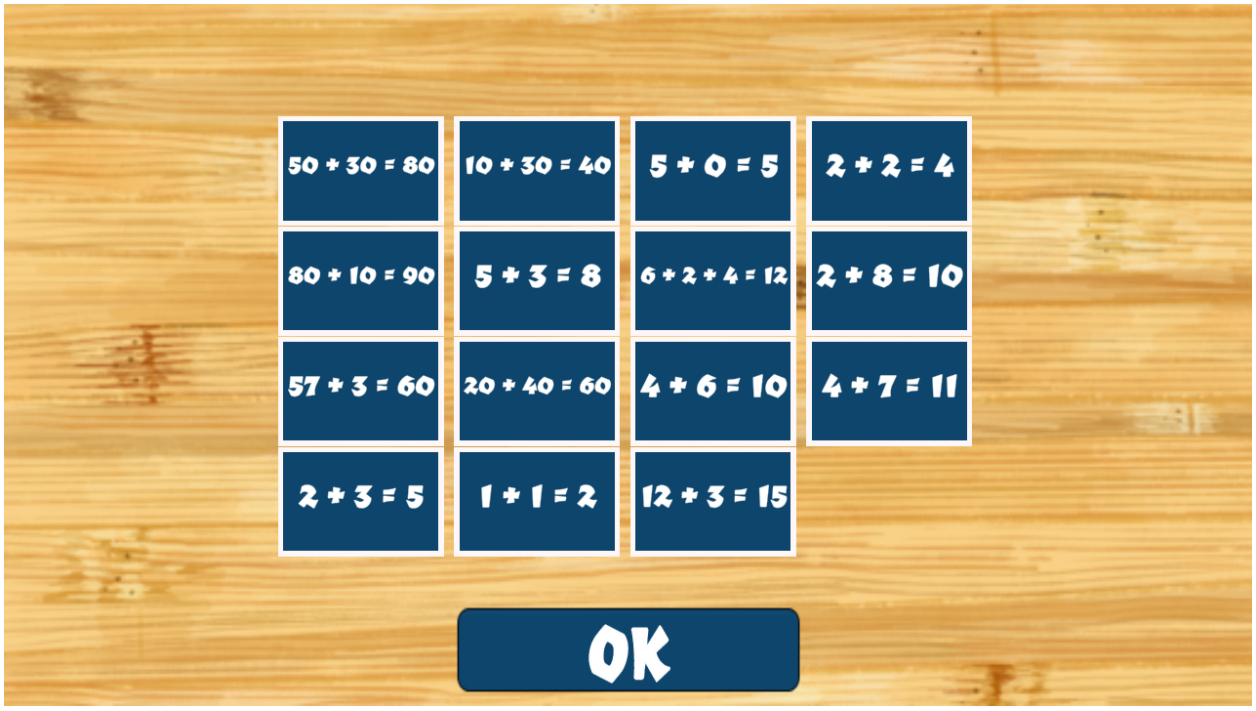
Score

After completing a level, the players are able to see how many problems they got correct, how much time they spent, how many stars they were rated, and are potentially able to earn a comic if they did well enough.



Problem review

Players are then able to see all of the problems they solved in the level and what ones they got wrong, if any.



Points earned

Finally, players are able to earn currency to use in the shop. How much they earn depends on the level difficulty and how many problems they got correct.

Learner Analysis

From my learner analysis, I attempted to understand the target audience in two ways. First, I read research on the psychology of learners in this demographic (1st-3rd graders). My research led me to identify four types of students to target with this project, which I explain below. Second, I conducted observations of young learners playing educational apps and was able to apply the personas to the children I observed.

In the following section, I first present observational data. I then present personas that represent the different types of learners that might use the game we are developing. These personas are based on the convergence of my own observations and the extant research.

Data

In order to inform my learner personas, I collected data through observations and interviews. Due to the COVID-19 quarantines and stay-at-home orders, I was limited in my ability to observe young children playing educational games on mobile devices. However, I was able to have my 8-year old sister and cousin test different apps I felt would be similar to the project. Although they are both in second grade, they are at very different math levels and have different attitudes towards math.

Observation Procedures

I researched available apps that were aimed at the same target demographic that taught math using the platform genre. I also ensured that the games were all highly rated, so as to choose those that had been well-received. I included a non-math platformer for comparison between a game with an entertainment focus versus one with an educational focus. The apps I chose were: Yash Math Adventure Game, Monster Math, Rayman Adventures, and Twelve a Dozen. Prior to observation, I developed the following protocol to record students' reactions to the different apps.

Introduction: Tell the participant they are going to be testing four different apps. Encourage them to talk out loud about what they are thinking as they play. Tell them they can choose when to move on to the next game.

Questions to observe (each app):

- How long did they spend on the app?
- What were they excited about?
- What were they frustrated about?
- What were their reasons for putting down the app?

Questions to ask (after each app):

- What did you like about that game?
- What didn't you like about that game?

Results

Main findings from data gathered:

- Both learners got stuck in certain places and talked about their frustration, but the Overachieving Learner would ask for help ("How do I get past this part?", "Where do I go

now?", while the Disadvantaged Learner would just quit ("I can't figure out how to get up there," "I don't know what to do next, can I play the next game?").
- The Overachieving Learner wanted to play all of the games longer.
- They both thought all games were fun initially ("Wow, this is cool!", "This is really fun!").
- They were motivated by dramatic story elements like running from an explosion or rescuing a kidnapped friend ("Everything's blowing up! We gotta hurry!", "It took my friend!", "I have to save my friend!").
- The Disadvantaged Learner would get frustrated by difficult gameplay, not so much difficult math ("I can't figure out how to get up there," "That's a huge jump").
- They were confused when there wasn't enough feedback when they were wrong or when there wasn't a clear objective to start out.
- They both liked earning a pet (Aww, I get a cute little dragon named Vern!").
- They loved getting awarded three stars, the Disadvantaged Learner especially ("Ooo, I got three stars!", "Yes, I got three stars!").
- They Liked killing/destroying things ("Look who I'm fighting now!", "Look at this! I will kill you!").
- They didn't like unfair gameplay ("There's a fake block!", "The robot stole my candy!").
- They liked flashy fighting moves.
- They wanted to be able to skip cutscenes ("Ugh, why can't I skip it?").

Learner Types

Four main personas emerged through this analysis (observation and literature review): the unengaged learner, the overachieving learner, the disadvantaged learner and the average learner.

The Unengaged Learner: This persona is based off of the many students who are simply not engaged when learning math and who are motivated primarily by external rewards. Studies show that attitudes towards a subject may affect achievement and behavior (Adelson & McCoach , 2011; Bandura, 1977). In contrast to the unengaged learner, students who are attentive and engaged in learning math tend to enjoy the subject and have high self-efficacy in regards to their mathematical abilities. These students also tend to persist even in the face of challenge.

Unengaged students need to practice more math in order to improve their skills and self efficacy. They also need something to help them enjoy practicing math.

The Overachieving Learner: Jade's persona is primarily based on observing my sister. She is cognitively ahead of her grade level in most skills and is often bored with the lack of challenge. Jade is very interested in math and intrinsically motivated to learn and solve problems. She needs something to challenge her and allow her to move past her grade level to harder math problems.

The Disadvantaged Learner: Lucy's persona is partially based on observing my cousin. She is multiple grades behind in her math skills and really struggles as the class moves ahead with harder and harder concepts. As she does math worksheets, she needs help on every problem and constantly talks about how she just doesn't get it. Her parents both work full time and don't have the time to reteach her everything.

Additionally, research shows there are significant math achievement gaps that occur in the U.S. by the time students reach elementary school (Garcia, 2015). These gaps can largely be explained by socioeconomic backgrounds, race, and ethnicity. When these inequalities occur so early in life, interventions are needed to reduce them before they affect a student long term.

Disadvantaged learners need time to go back to the fundamentals and practice math skills at their level. They also need to feel like they are smart enough to learn math.

The Average Learner: This persona is based off of students who are considered average. They aren't underachieving or overachieving and may often be overlooked by teachers and parents. However, with a little encouragement, these students may be able to expand their potential, especially when it comes to math.

Personas

Based on my research and observations, I created the following personas. These are fictitious learner profiles rooted in real observations and research. They can be shared with other design and development team members to communicate learner needs and personalities throughout the project.

The Unengaged Learner

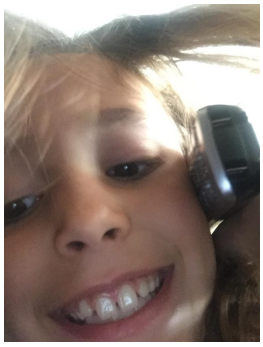
Name: Kendrick
Grade: 1

Bio: Kendrick is easily bored in school and his favorite time is recess. He is usually chatting with his friends instead of paying attention to his teacher. Although he doesn't naturally struggle in school, he doesn't care enough to do well and often performs poorly in math. Kendrick's parents make him do his homework, but they usually have to bribe him with something fun, like time to play video games or time to play with his friends.

Needs: Kendrick needs to focus more on the math he is learning in school. He also needs to spend more time practicing and doing quality work, instead of just rushing through his homework. Kendrick needs to see that it's easier to do well the first time, instead of having to repeat work over and over.

Motivations: Kendrick doesn't care much about school, but he does care about appearing cool in front of his friends. Sometimes he feels bad when he doesn't get as high of a score as someone else on a math test or worksheet. Kendrick is highly motivated and competitive when he considers something a game. He is also very motivated by rewards.

Parent Motivations: Kendrick's parents care about him doing well in school, but have given up on him caring intrinsically. Instead, they have resorted to external rewards to motivate him to do his work. Ideally, they would like to use something that would engage Kendrick in learning, but they would also settle for something that would just motivate him to learn in some way, without them having to think of rewards for him.



The Overachieving Learner

Name: Jade
Grade: 2

Bio: Jade excels in every school subject and often lacks challenge, especially in math. She frequently calls her older sister (who lives away from home) to ask for a hard math problem. Jade is the youngest child and is often ignored at home and left to her own devices. She has very high energy and always needs to be doing something. She loves playing games, but her mom doesn't like her wasting time. Sometimes her mom will allow Jade to play games on her phone if they are out of the house and Jade needs to be quiet.

Needs: Jade needs more entertainment at home, where she is often ignored. She also needs something to stimulate her overactive brain. Jade's parents don't like her wasting time but also need to entertain her, so Jade needs an activity that is worthwhile or that she learns something from.

Motivations: Jade loves reading, art, and solving hard problems or puzzles. With math, she would like to have more challenge and go beyond what she's learning in school. She loves when her sister gives her math problems that are put in story terms or are part of a game. She appreciates a good story and likes fun characters. Jade is most motivated by games that challenge her and have some sort of character customization. She is also highly motivated by praise and hates when she fails at something.

Parent Motivations: Jade's parents wish they could offer her more learning challenges, but they don't have the time to come up with things on their own. They feel guilty that she isn't living up to her learning potential and don't want her to waste time. Jade's parents would purchase something that challenges her beyond her grade level and would love if they didn't have to do any work to achieve this.

The Disadvantaged Learner

Name: Lucy
Grade: 3

Bio: Lucy is an English Language Learner and often struggles in school, especially with math. Although she is in third grade, she still hasn't mastered concepts taught in earlier grades. Because she doesn't have much of a math foundation, Lucy feels like she is falling further and further behind, which makes her want to stop trying in school. Lucy's family has low socioeconomic status and her parents both work, leaving little time for them to help with homework.

Needs: Lucy needs to relearn math concepts from earlier grades in order to catch up to her peers. She needs to spend time practicing lower-level math skills outside of school, as well as be provided with the content to do this.

Motivations: Lucy is embarrassed when she isn't able to understand the same math as her friends. She wants to feel like she is good at something, but she tends to tune out when things get too hard. Lucy wants a safe and non-embarrassing way to practice lower-level math skills. She is motivated to learn as long as the learning isn't too complex and is framed in a fun way. Lucy is also motivated by praise, which she doesn't receive much at school. She needs something that would motivate her to practice math at home after a long day at school.

Parent Motivations: Lucy's parents are aware she is behind in school, but they don't have the time or means to help her. They would be willing to spend a little money on something that would help Lucy catch up to her grade level in math and put her on a path for a bright future.

The Average Learner

Name: Jared
Grade: 2

Bio: Jared performs averagely in all school subjects. He isn't particularly interested or disinterested in math, but completes all assignments. Jared occasionally needs help from his teacher and parents, but adequately hits all of his grade benchmarks.

Needs: Jared needs a way to see math as fun and interesting. He needs encouragement to practice math and increase his skill. It would also help Jared to see how math could be useful in life outside of school.

Motivations: Like most children his age, Jared does what he is asked to in school, but cares more about friends and having fun. When he thinks something is cool, he will be more likely to participate and try his best. Jared plays video games in his spare time and loves beating every level.

Parent Motivations: Jared's parents want him to do well in school, but are satisfied as long as he is hitting the benchmarks for his grade. They are busy with multiple kids and aren't always able to come up with educational activities for Jared outside of school, even though they would like him to be productive. Jared's parents would purchase something that would help him learn in a fun way.

Summary

Through my observations and interviews, I have selected some key design implications that influenced the finished product.

- The game should include opportunities to get help and encourage players to get help if they are stuck. There should be clear objectives and feedback.
- The game should include dramatic story elements to create excitement for players.
- The non-academic gameplay itself should not be very difficult and should also be fair. The focus should be the math.
- Players should receive rewards and ratings.
- The game should include cool "moves" and opportunities to destroy things.

Environmental Analysis

Stakeholders

Number Ninjitzu is based on an idea from Peter Rich, who wanted a way to make a math worksheet more engaging without compromising on the math practice. He decided to start developing plans for a mobile game with a strong storyline. Peter decided on a platformer game and worked with artists and a writer on and off for a few years, but the progress stopped and he was considering cutting the project. However, I spoke with him about my interest in educational game design and he suggested I develop the app for my project. Although none of the programming had been completed, the art for the game was very high quality and we didn't want the talent to go to waste. We expect the app to give the math practice of a worksheet, but the gameplay will be fun enough to engage children to where they want to practice arithmetic.

Environment

Learners experience the practice of a math worksheet through a platformer game, a familiar game genre for many young children. The app will be published for IOS and Android, and is playable on tablets and phones, but the main target is tablets because they are bigger and will fit the platformer/math gameplay more comfortably. Many children are familiar with mobile games, so the environment is comfortable to them. The non-academic gameplay is fairly easy for children to master, because the focus is on the math and not difficult gameplay. The setup of the game is simple and straightforward for young learners. Controls for the game are easy to figure out and clearly marked.

Constraints

Some constraints for this project include the type of game being made, the game story, and the game artwork, because these were mostly decided before I became involved. There weren't any budget constraints, as the main cost was just the hourly pay of the people involved in the project. I was in charge of the instructional and experience design aspects of the game. We also have two programmers and an artist.

Research Analysis

Surveys have found that children aged 2-12 spend an average of two hours a day playing mobile games, and this age group is the second-highest age group for money spent on games and in-app purchases (Tofel, 2015). Many parents are setting up their children to play mobile games throughout the day. This reinforces our decision to create the project as a mobile game in order to reach many children.

Additionally, 47% of students have consistent access to mobile devices in the classroom (Project Tomorrow, 2015). Educational apps are becoming popular inside and outside the classroom.

Implications

- The core focus should be on the math practice a worksheet offers, while making it engaging.
- Many assets have already been developed for Number Ninjitzu (artwork, story, and basic game design). The game should make judicious use of what's already been developed.
- Children are very comfortable with mobile games. Tablets will be targeted as the main platform, but the game should also work on phones.

Consulting Products/Precedent

I analyzed several math games and platformers to learn what is and is not effective in this type of game. In order to find similar products, I researched and played three top math apps for kids, three top platformer apps, and three math platformer apps (see Table 1). The following section provides a brief analysis of each. This is then followed with a few key implications for the design of Number Ninjitzu.

Table 1
Math and Platformer Apps Consulted for Comparison

Math apps	**Platformer Apps**	**Math Platformer Apps**
Prodigy SplashLearn Khan Academy Kids	Rayman Adventures Dan the Man Swordigo	Twelve a Dozen Yash Math Adventure Game Monster Math

The following section briefly introduces each of these apps. I then describe what I learned from playing these apps and the implications for the design of Number Ninjitzu.

Top Math Apps for Kids

Prodigy:

In Prodigy, kids can earn rewards, go on quests, battle with magic, catch pets, and play with friends, all while practicing math aligned with state-level curricula. The content is tailored to each player.

Prodigy does a great job at giving learners a customized experience. Players can create their own character, choose what quests to go on, participate in fun events, and interact with friends. This open-world environment makes learning flexible and fun. Rewards in the game are exciting, from earning new magical abilities to rescuing new pets. We can take this concept for Number Ninjitzu and work on adding many customization options for players.

SplashLearn:

SplashLearn has many different interactive math games that are curriculum aligned. Players can earn coins and redeem them for virtual pets.

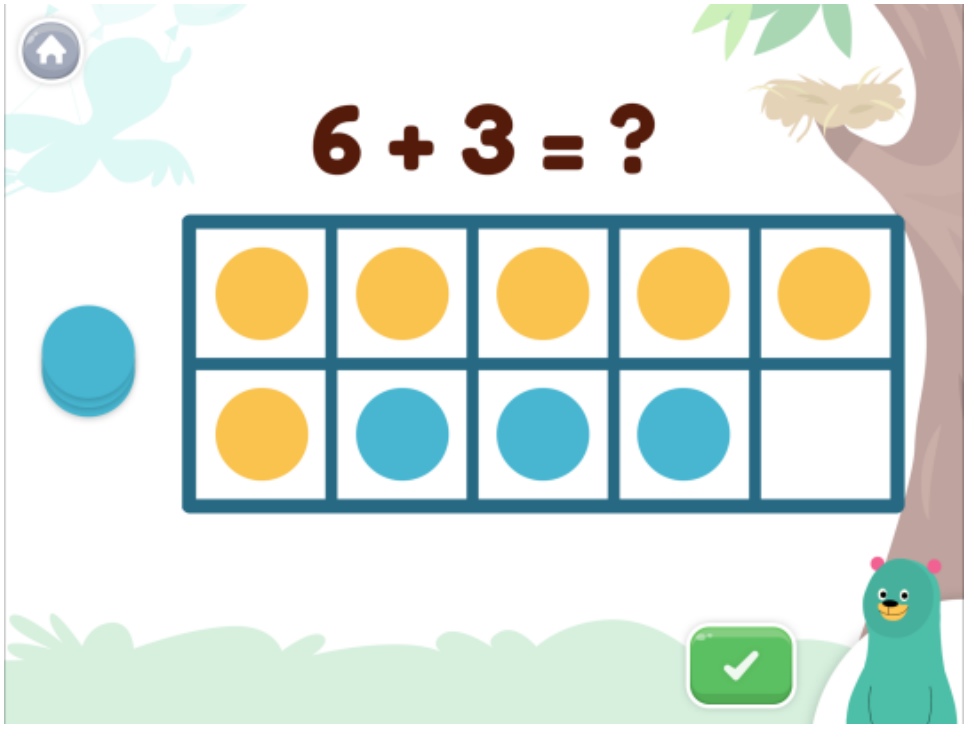
This game does well at providing variety by allowing players to test out many different mini games and find their favorite ways to learn math. The game provides encouragement through verbal encouragement and the ability to earn coins and redeem them for virtual pets. Both of these things provide a fun environment and push kids to keep learning. Additionally, the game features a progress bar to show children how much they've learned. We can use these practices in Number Ninjitzu by placing emphasis on both verbal or written encouragement, as well as using fun rewards to motivate children to keep playing. The levels and scores in Number Ninjitzu will help learners see how far they've progressed.

Khan Academy Kids:

Khan Academy Kids is a free educational program that makes learning fun. It has a robust curriculum that includes more than math, and makes content engaging through fun characters and games.

This game does well at presenting a storyline with engaging characters. The characters are cute animals and are presented as friends and mentors. The player gets to learn while being guided by these characters. Number Ninjitzu also features a mentor character who will guide players along the story of the game and give a basis for the math in the game.


Khan Academy Kids
Teddy


6 + 3 = ?

Top Platformer Apps

Rayman Adventures:

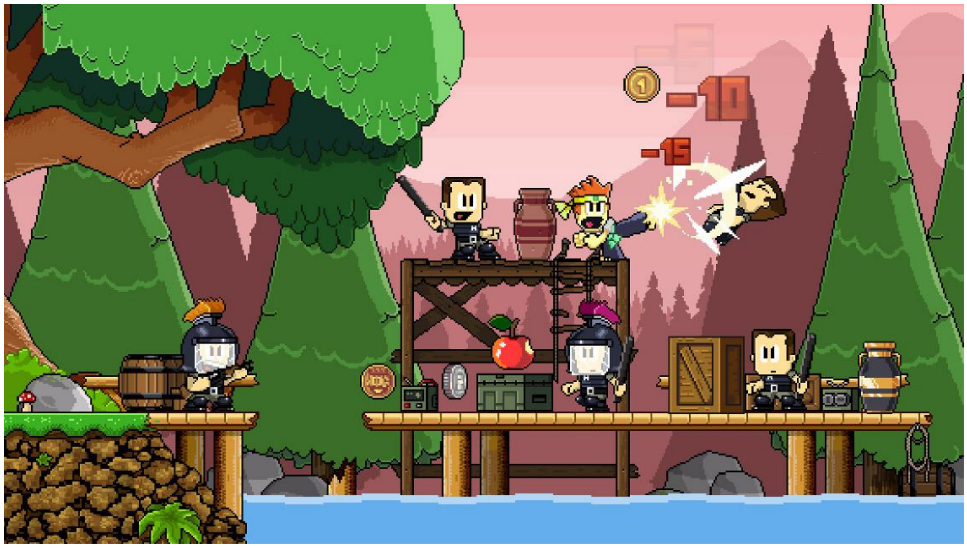
In Rayman Adventures, players embark through an enchanted forest and many other worlds to help Rayman and his friends on their quest. With fun playable characters, beautiful visuals, and exciting runs and battles, Rayman Adventures is extremely entertaining.

This game does well at presenting a lot of colorful characters and locations. Unlocking new characters and locations is based on performance and completion of previous levels, motivating players to keep playing to unlock more. Rayman Adventures also includes helpful rewards that players can earn, in the form of power boosts. These add customization to the game and continue to motivate players to perform well. Number Ninjitzu also has interesting locations that players unlock as they complete more levels. The game will also feature the ability to earn new moves to use in later levels.

Dan The Man:

In Dan The Man, players can enjoy a retro action platformer that makes them feel like they're in an old arcade. The game also includes a funny story, upgradeable skills, and epic weapons.

This game does well at presenting an interesting and continuous story. The story is in the form of a quest and focuses on one character's journey throughout the game world. Dan the Man also does well at giving players useful rewards. By collecting coins throughout the game, players can purchase special weapons or powers to help them defeat enemies. This adds an element of customization and motivation to continue playing to earn more rewards. The story in Number Ninjitzu is also continuous and in the form of a quest. By performing well in each level, players can spend their points on rewards in the game store. However, the rewards aren't really useful for gameplay, so this is something to think more about.



Swordigo:

In Swordigo, players run and fight their way through an epic adventure. With magical realms, characters who can gain more skill, powerful items, and an engaging story, this game will draw players in.

This game does well at presenting an engaging story with exciting locations. The story in Swordigo is in the form of a quest and the main character travels to many different places to achieve their goal. Swordigo also provides players with helpful rewards, like better weapons or increased power. Number Ninjitzu has a quest storyline as well and allows players to purchase rewards with points they've earned.

Math Platformer Apps

Twelve a Dozen:

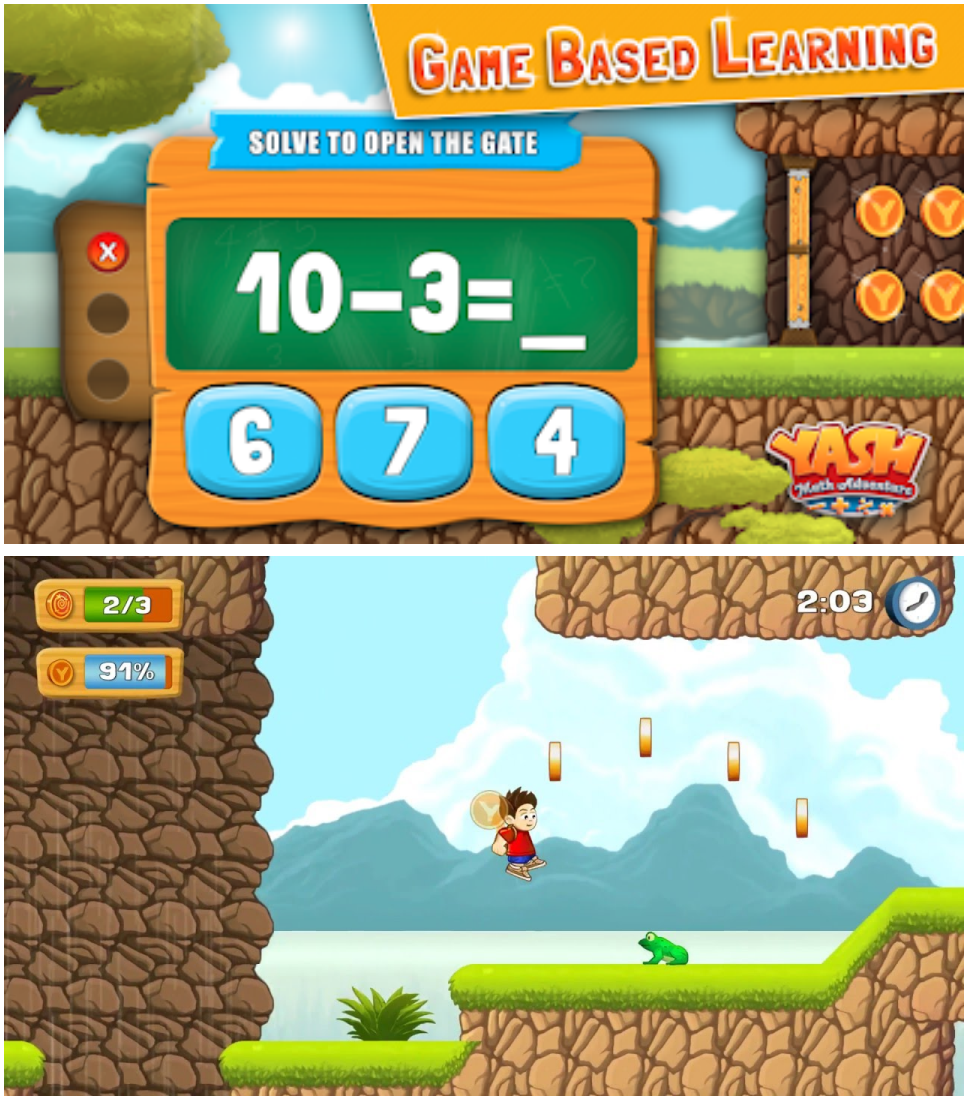
In Twelve a Dozen, players are on a journey to save Dozenopolis. They solve simple math problems that gradually get more complex. The character earns the ability to become different numbers and each number has a special power.

This game does well at presenting an exciting story. From the beginning of the game, there are many dramatic elements that create an atmosphere of excitement and urgency. Twelve a Dozen has a narrator that tells the story and guides the player through the game. Additionally, players are given the chance to earn new abilities as they progress through the levels. Also, the math is purposeful and moves the adventure along. Number Ninjitzu has an exciting story, as well as a mentor figure that guides the player along. Number Ninjitzu similarly gives players new abilities (moves) as they progress through the levels. The math in Number Ninjitzu also has a purpose relevant to the story.

Yash Math Adventure Game:

In Yash Math Adventure Game, players are on an adventure, and their goal is to make it to the end of the level and collect coins on the way. There are many barriers, which can only be unlocked by completing arithmetic problems. The difficulty level for the math can be set by the player.

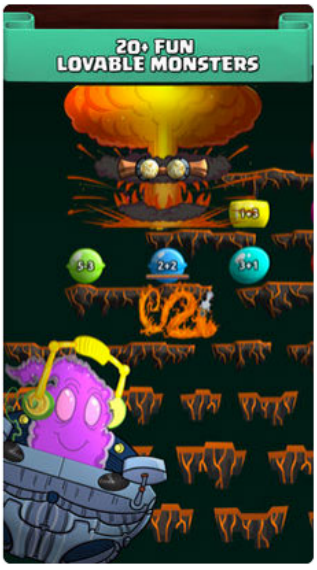
This game provides rewards in the form of coins, but they can't be used to purchase anything. The math is somewhat purposeful, but only to remove barriers and it isn't really relevant to the story. Number Ninjitzu can improve on this game by allowing the players to purchase rewards with the points they've earned. Additionally, the math in Number Ninjitzu is relevant to the story.



Monster Math:

In Monster Math, the player is a monster who is trying to save their kidnapped friend. Players solve math problems aligned with Common Core in order to progress through the storyline and defeat bad monsters.

This game does well at presenting an interesting storyline and funny characters. From the beginning of the game, there are dramatic elements like the main character's friend getting kidnapped, that add excitement and urgency to the game. The characters in the game are colorful and have funny lines. However, there isn't much of a reward system. Number Ninjitzu has an exciting storyline as well, and features humorous dialogue.



Implications

In summary, there are a few main implications found after consulting similar products. First, popular math and platformer games often include interesting characters, many exciting rewards, and some type of adventure story. These three things will be the main non-academic focuses of our project in order to engage children and make them want to play the app. Second, in the popular games that include math, players are required to do math in order to either earn something, or get past some kind of barrier. These principles will be included in the project and no math will be purposeless to the game. Finally, the most popular games include different types of rewards, such as skill upgrades or currency to purchase rewards like clothes, weapons, and

pets. Following this, the project should include different types of fun rewards, enough to make more play desirable, but not enough to create confusion.

Annotated Bibliography

To better understand how to design an effective elementary math game, I reviewed literature in several areas. First, I looked at research on young students' math knowledge. This led to an understanding of the need for mental math. Second, I analyzed literature on several educational psychological principles that I thought might be relevant to guide young students' learning in a game that is essentially an assessment. Third, I reviewed literature specifically aimed at designing games. Each of these are briefly reviewed in the following section which each end with a brief overall synthesis of that literature.

Domain Knowledge

Hope, J. (1985). Unravelling the Mysteries of Expert Mental Calculation. *Educational Studies in Mathematics, 16*(4), 355-374. Retrieved June 3, 2020, from www.jstor.org/stable/3482445

This article dives into common tricks and tips expert mental math calculators use to be so efficient. The three main strategies - additive distribution, subtractive distribution, and factoring will be useful in deciding what mental math tips to include in the project. Since the project is all about automaticity and fluency, teaching children how to do smart mental math will be important.

Common Core State Standards for Mathematics (n.d.). In Common Core State Standards Initiative. Retrieved from http://www.corestandards.org/wp-content/uploads/Math_Standards1.pdf

These standards cover the math students will need to understand from 1st-3rd grade and show the math progression from grade to grade. The math included in the project will be based off of the standards in this document. The document is helpful in showing how to break down the math in each grade and will allow us to split the math between levels.

Adelson, J. L., & McCoach, D. B. (2011). Development and Psychometric Properties of the Math and Me Survey: Measuring Third Through Sixth Graders' Attitudes Toward Mathematics. Measurement & Evaluation in Counseling & Development, 44(4), 225. doi:10.1177/0748175611418522

This article discusses the Math and Me Survey, which was designed to measure students' attitude towards math, especially when it comes to enjoyment and self perceptions. Students who enjoy math more and are more confident in their abilities tend to be more attentive, engaged, and persistent in the face of challenge. This knowledge is useful for our project, since we are attempting to make math more enjoyable.

Bharathi, A., Singh, A., Tucker, C. S., & Nembhard, H. B. (2016). Knowledge discovery of game design features by mining user-generated feedback. Computers in Human Behavior, 60, 361.

In this article, researchers used an algorithm to discover what game elements were present in successful apps. The top individual six game elements found in successful educational apps were found to be Points, Badges, Leaderboards, Levels, Virtual Goods, and Avatars. This information is important since we want to model our game after other successfully designed games. The project will include most of these popular game elements.

Synthesis

These articles provide some of the background knowledge necessary for designing this game. Understanding what content to cover for first through third graders is essential for the game to be valid. Understanding mental math strategies and the effect of student attitudes in math will help design for better learning. Finally, understanding what popular game elements to include will be important in making the game successful.

Instructional Strategies

Morgan, P. L. (2018, August 18). Should U.S. Students Do More Math Practice and Drilling?. In Psychology Today. Retrieved from https://www.psychologytoday.com/us/blog/children-who-struggle/201808/should-us-students-do-more-math-practice-and-drilling#:~:text=Routine%20practice%20and%20drilling%20following,to%20solve%20more%20c

This article discusses how more math practice and drilling may help students, especially those struggling. The routine practice will help students become quick and accurate, or fluent, in solving math problems. This article also talks about how providing corrective feedback and setting goals are important. Students becoming fluent in math is the main goal of our project and this information backs up our attempt to attain this through drilling. In addition, this article is useful in describing the benefits of corrective feedback, which we will want to include in the game.

Nakamura, J., & Csikszentmihalyi, M. (2014). Flow and the Foundations of Positive Psychology (pp. 239-263). N.p.: Springer, Dordrecht. Retrieved from https://link.springer.com/chapter/10.1007/978-94-017-9088-8_16

This chapter describes the concept of flow, or the mental state a person is in when they are completely immersed in an activity. Achieving flow requires a balance between challenge and skill. High challenge and low skill will cause anxiety. Low challenge and high skill will cause boredom. Challenge and skill need to be equally matched and increase with each other. This principle has important implications for Number Ninjitzu. The level difficulty must increase in a way that keeps challenge and skill in balance.

Riel, M. M. (2000, January). Education in the 21st Century: Just-in-Time Learning or Learning Communities. In ResearchGate. Retrieved from https://www.researchgate.net/publication/258698171_Education_in_the_21st_Century_Just-in-Time_Learning_or_Learning_Communities#:~:text=Education%20in%20the%2021st%20Century%3A%20Just%2Din%2D,Time%20Le

This article describes the concept of just-in-time learning. Just-in-time learning makes help readily available right when a learner needs the information. This flexible method is predicted to revolutionize schools and learning methods, due to technology providing information quickly. In Number Ninjitzu, we aren't going to take the time to teach math concepts, because our focus is on learners practicing their skills. However, in accordance with just-in-time learning, we will provide short math examples and tips right before a level starts.

Brosvic, G. M., Dihoff, R. E., Epstein, M. L., & Cook, M. L. (2017, May 27). Feedback Facilitates the Acquisition and Retention of Numerical Fact Series by Elementary School Students with Mathematics Learning Disabilities. The Psychological Record. doi:https://doi.org/10.1007/BF03395536

This article discusses the benefits of immediate feedback. When students were given delayed feedback, there was no learning benefit found, but immediate feedback proved to be very beneficial for improved performance, especially in students with a learning disability. Immediate feedback will also be beneficial for the learners in Number Ninjitzu. After each level, learners will be able to review the problems they got correct and incorrect.

Synthesis

These articles describe the learning strategies we will focus on in the academic side of the game. First, practice with immediate feedback is important in improving math fluency. Second, learners should face a balance of challenge and skill in order to be immersed in the learning. Third, just-in-time learning tips will give students the immediate help they need for attempting each level.

Design Approaches

Mahfuzah Mohamad, S., Safwana Sazali, N., & Mohd Salleh, M. (2018). Gamification Approach in Education to Increase Learning Engagement. International Journal of Humanities, 4(1), 22-32. doi:https://dx.doi.org/10.20469/ijhss.4.10003-1

This article discusses the popularity of mobile learning that uses game elements. Applications can make learning more attractive and allow students to be more engaged in their learning since they feel like they are playing an entertaining game. Additionally, the article gives one five-step method for implementing gamification features in order to increase user learning engagement. The steps in the model are Determining Student Intelligences, Defining Learning Goals, Structuring Learner Experience Content & Activities, Interactive Design Interface, and Applying Game Elements. The principles involved in making learning attractive through games benefit and justify our project and the included model will be useful to reference throughout the design process.

Lopez, C. E., & Tucker, C. S. (2017). A quantitative method for evaluating the complexity of implementing and performing game features in physically-interactive gamified applications. Computers in Human Behavior, 71, 42.

These researches studied game features in physically-interactive applications. The purpose of the gamification was to motivate individuals to complete the tasks given to them in order to improve their health. The study found that the game elements of Points and Avatar had a significant positive impact on the participants' motivation and performance in the apps. This is useful to the project and encourages us to strongly utilize the elements of points and avatar to increase motivation and performance in the students using the app.

Rodrigues, L., Oliveira, A., & Costa, C. J. (2016, August). Does ease-of-use contributes to the perception of enjoyment? A case of gamification in e-banking. Computers in Human Behavior, 61, 114-126. doi:https://doi.org/10.1016/j.chb.2016.03.015

In this article, researchers discovered that ease-of-use and enjoyment have a positive influence on each other. Participants tended to be more engaged and enjoy the application if the software was easy to use. This finding can be applied to our project on the design side. Our audience includes young children, which makes it even more important to ensure our app is easy to use.

Dickey, M. D. (2007, September). Game Design and Learning: A Conjectural Analysis of How Massively Multiple Online Role-Playing Games (MMORPGs) Foster Intrinsic Motivation. Educational Technology Research and Development, 55(3), 253. doi:10.1007/s11423-006-9004-7

When users are given more choices, like character development, and control over their course, their intrinsic motivation grows. Users become emotionally attached to their characters and journey. Flexibility seems to be a key in designing for engagement and we should focus on flexibility, especially when it comes to characters, in the project.

Synthesis

These articles address important design advice when it comes to mobile games. Games can help make learning more attractive to students and motivate them to practice more. When players are given more flexibility and choices in a game, they will become even more invested and engaged. Finally, the game should be easy to use in order to increase enjoyment. Although it has been shown that presenting learning in the form of a game increases motivation and engagement, there are gaps in the literature when it comes to whether or not games improve academic performance.

Design Specifications

Structure
For my project, I proposed the design of a mobile game for iOS and Android. The app is called Number Ninjitzu. The game is a platformer with a ninja theme. First through third grade arithmetic is included in the game in order to give students the opportunity to practice their math skills.

Learning Goals
Number Ninjitzu helps students achieve the goal of improving math fluency by allowing students to practice their math skills. They solve arithmetic problems in each level and the problems become more difficult as the game goes on. Learners are encouraged to advance to and practice more difficult levels through increasingly valuable rewards that can be unlocked as they earn in-game currency for practicing arithmetic.

The game achieves the goal of making math practice more engaging by providing a fun and purposeful environment for learners to practice. The game includes interestings characters, a storyline, and exciting rewards.

We achieve the goal of making the game accessible to the public by creating Number Ninjitzu in the form of a mobile game. Many children have access to mobile devices and they will be able to download the game from the IOS or Android store.

Design
The design for the game is based off of research done on improving math fluency and research done on increasing engagement through educational games. Students need more drilling practice in order to become fluent in math, but they also need something that makes them want to practice. Our goal is that Number Ninjitzu will make a worksheet engaging, which will increase practice time for learners, which should increase overall fluency for math facts.

The design for Number Ninjitzu takes advantage of precedent established by mobile games by including common elements from top platformer and math apps.

The design for the game uses a predetermined game type, game artwork, and game story. However, these shouldn’t affect the instructional aspect of the game and all are of high quality.

Design Representations/Prototypes

The following image shows a breakdown of the math grade standards by level. I gave all of the standards an equal weight and arranged them to be equally distributed between all of the levels and build upon each other in difficulty.

16 Level Breakdown

1st Grade

Level 1	Mental addition
Level 2	Adding in columns
Level 3	Mental subtraction
Level 4	Subtracting in columns
Level 5	Add and subtract

2nd Grade

Level 6	Mental addition (with and without regrouping)
Level 7	Adding 2-digit number in columns
	Adding 3-digit number in columns
Level 8	Mental subtraction
Level 9	Subtracting in columns
	Subtracting in columns (with borrowing)
Level 10	Multiplication with 2, 5, and 10

3rd Grade

Level 11	Mental addition
	Column-form addition
Level 12	Mental subtraction
	Subtraction in columns
Level 13	Multiplication facts
Level 14	Multiplying by multiples of 10
	Multiplying in columns
Level 15	Division facts
Level 16	Long division

The following image shows the first page from the type of math problems that were programmed into each level. I took these problem types from the math grade standards and tried to represent them so they were easy to program.

First Grade

NOTE: There can be no negative numbers anywhere

Purple = Where they will be putting in the answer

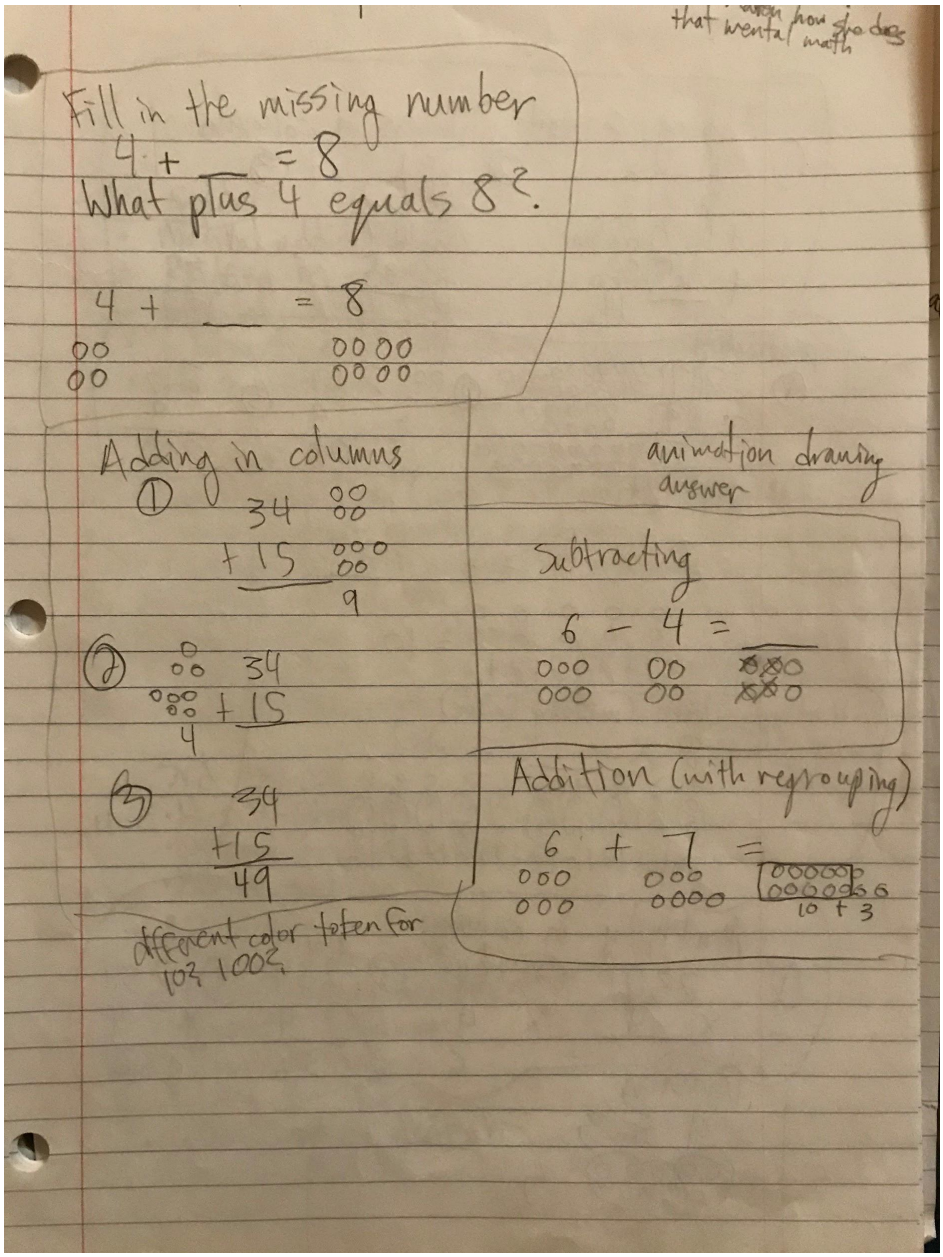
Level 1 - Mental addition

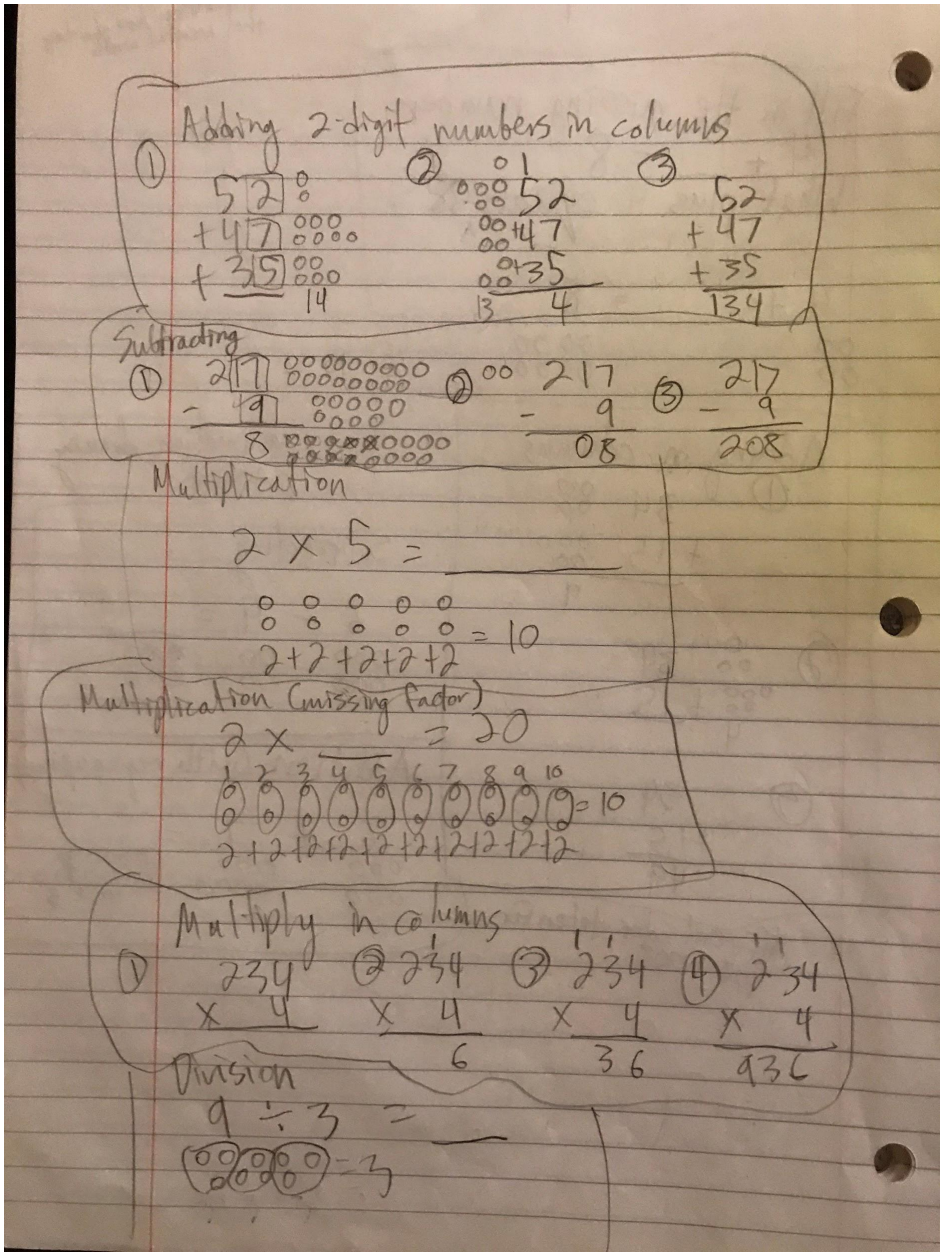
- 1. (Number between 0 and 10) + (Number between 0 and 10) = (Number has to equal 10 or less)
  - Ex: 2 + 6 = 8
- 2. (Number between 0 and 10) + (Number between 0 and 10) = (Number has to equal 20 or less)
  - Ex: 9 + 8 = 17
- 3. (Number between 0 and 10) + (Number between 0 and 10) = (Number between 0 and 10) + (Number between 0 and 10) + (Number between 0 and 10) = _____
  - Ex: 8 + 5 = 8 + 2 + 3 = 13
- 4. (Number between 0 and 10) + (Number between 0 and 10) = (Number has to equal 10 or less)
  - Ex: 2 + 5 = 7
- 5. (Number between 0 and 10) + (Number between 0 and 10) = (Number has to equal 20 or less)
  - Ex: 2 + 15 = 17
- 6. (Number between 0 and 10) + (Number between 0 and 10) + (Number between 0 and 10) = _____
  - Ex: 3 + 6 + 5 = 14
- 7. (Whole ten number between 10 and 90) + (Whole ten number between 10 and 90) = _____
  - Ex: 20 + 30 = 50
- 8. (Whole ten number between 10 and 90) + (Whole ten number between 10 and 90) = _____
  - Ex: 80 + 90 = 170
- 9. (Number between 0 and 100) + (Number that will round up first number to next ten) = (Whole ten number between 10 and 100)
  - Ex: 86 + 4 = 90
- 10. (2-digit number between 10 and 98) + (Number between 0 and 10, no carrying) = _____
  - Ex: 35 + 4 = 39

Level 2 - Adding in columns

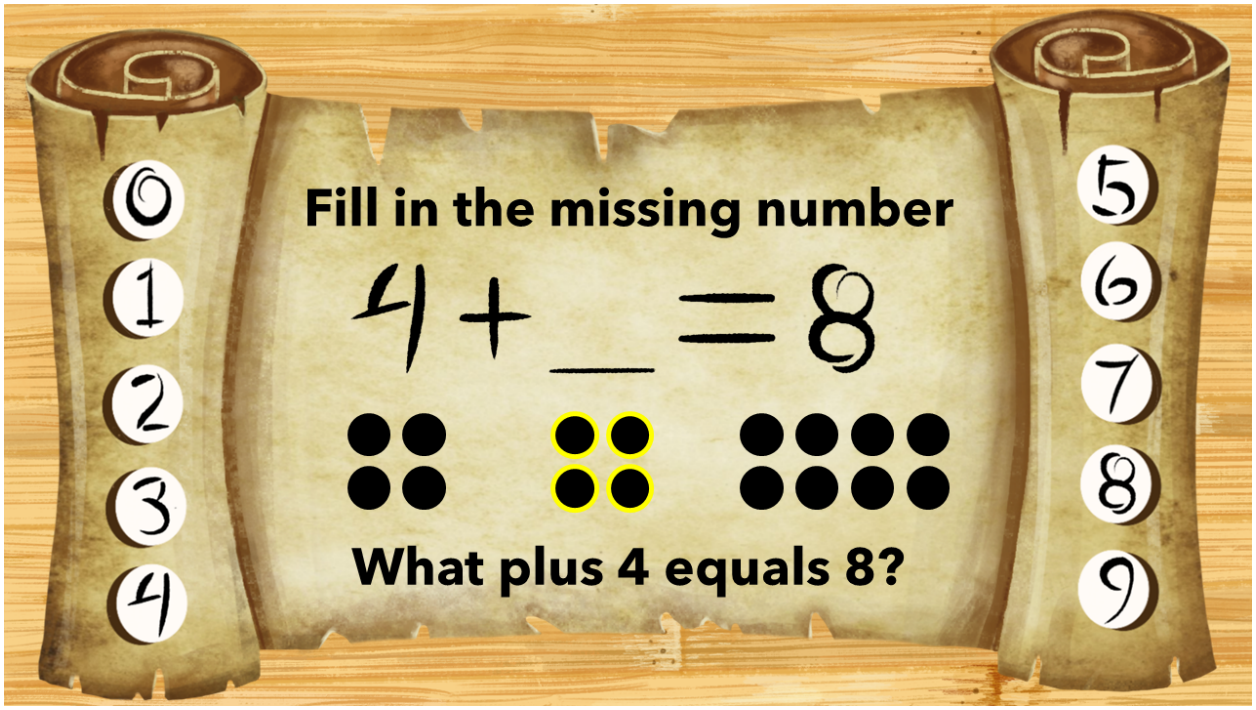
- 1. (Number between 10 and 99) + (Number between 0 and 10, no carrying) = _____
  - Ex: (this should be in column form) 35 + 4 = 39
- 2. (Number between 10 and 99) + (Number between 10 and 99, no carrying) = _____
  - Ex: (this should be in column form) 34 + 15 = 49
- 3. (Number between 10 and 99) + (Number between 0 and 10, no carrying) = _____
  - Ex: (this should be in column form) 26 + 3 = 29

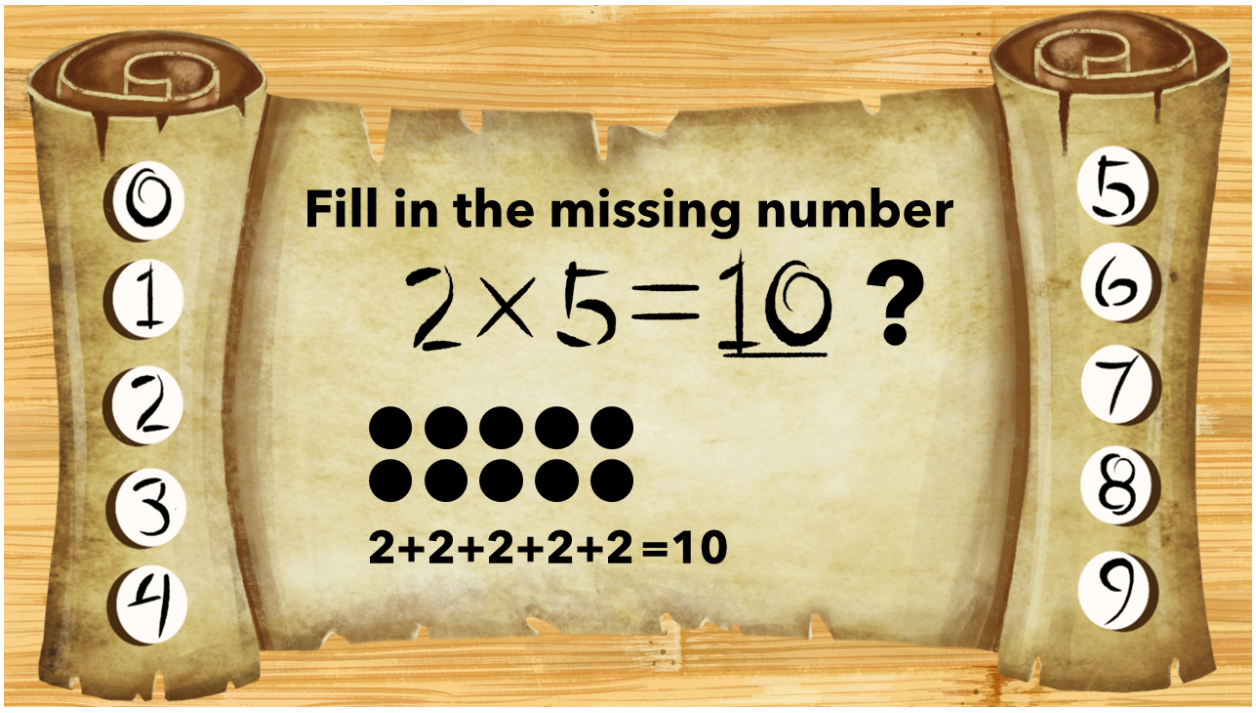
The following pictures show a mockup of what the pre-level, just-in-time learning helps look like in the game. Before each level, learners are able to view an example problem that relates to the new content in that level and shows them how to solve that type of problem. The first few examples use counters (the little circles in the drawings that break down each number) to help students visualize numbers better.

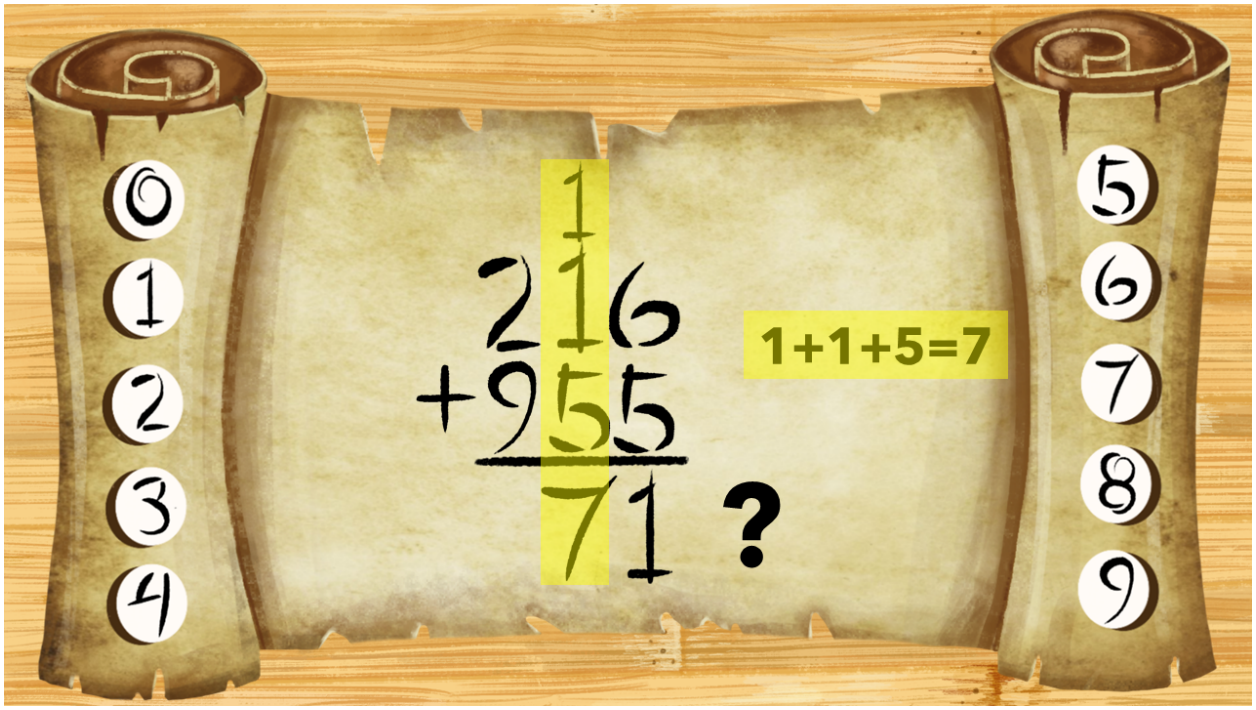



Adding 2-digit numbers in columns
52
+47
+35
14
52
+47
+35
134
Subtracting
217
- 9
208
Multiplication
2 x 5 =
= 10
2+2+2+2+2
Multiplication (missing factor)
2 x = 20
= 10
Multiply in columns
234
x 4
6
36
936
Division
9 ÷ 3 =
= 3

The following images show what actual pre-level, just-in-time learning helps look like.







The following is a picture of what opening a scroll looks like. The players solves a math problem on a scroll whenever they pick one up. The background is clean and focused to minimize distractions while answering questions.

Assessment Reports and Instruments

For Number Ninjitzu, assessment is built into the game by default, as it's the main focus of gameplay. Because of this, we were able to collect assessment data through the game itself using learning analytics. Some examples of data we attempted to pull are:

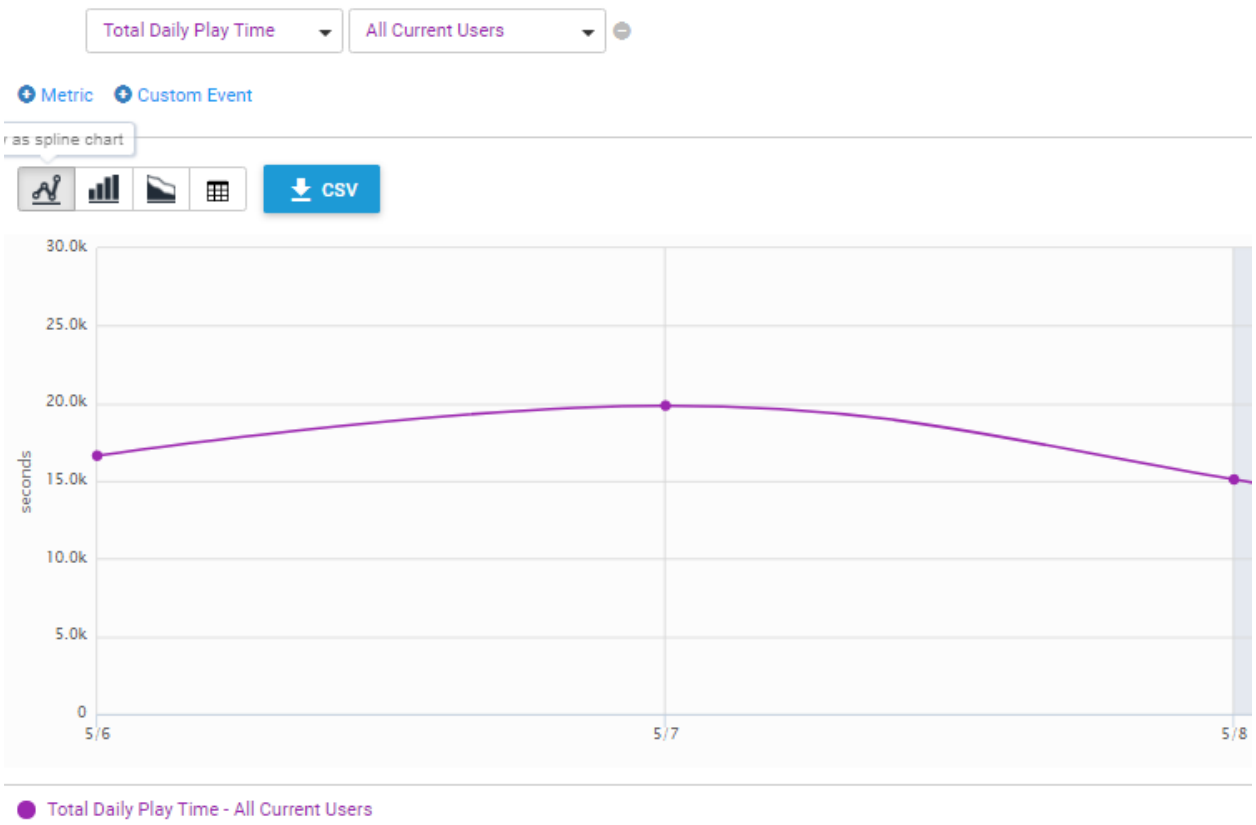
- How long do players spend on the game total?
- How long do players spend on the game per session?
- How long do players spend on each level?
- How many times do players replay each level?
- How do players improve in accuracy the longer they play?
- How do players improve in time the longer they play?
- What questions are the easiest to answer and what questions are most difficult to answer for players (based on time and accuracy)?

Additional assessments were used for the purpose of evaluating the two main goals of the project and are described in the Evaluation Instruments section below.

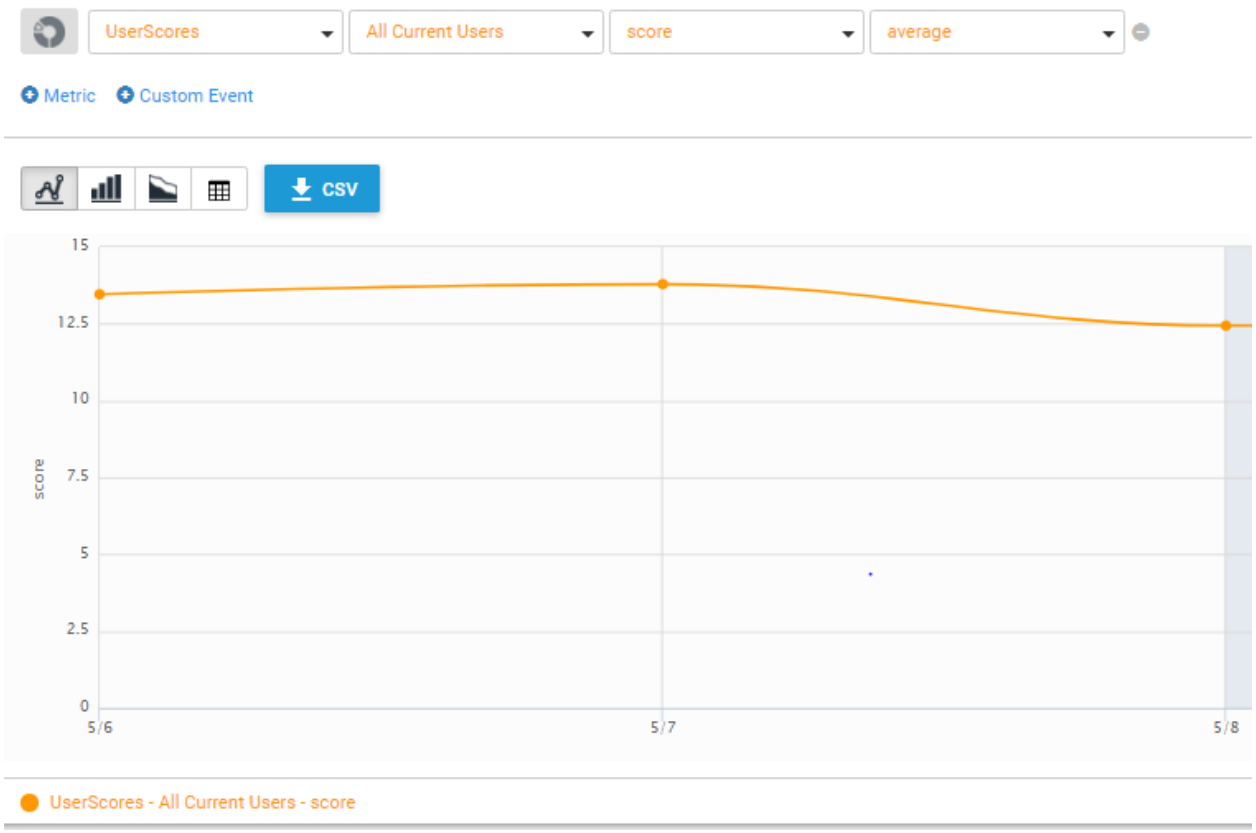
We gathered the analytics through Unity Analytics. Our programmer put in different custom parameters to try and track players as much as possible. Unfortunately, we weren't able to use Unity Analytics to answer all of the questions that we hoped to, but we still were able to pull some interesting data.

Some significant data we collected includes how much players played the game each day, what their average scores were, and what level difficulty they were playing.

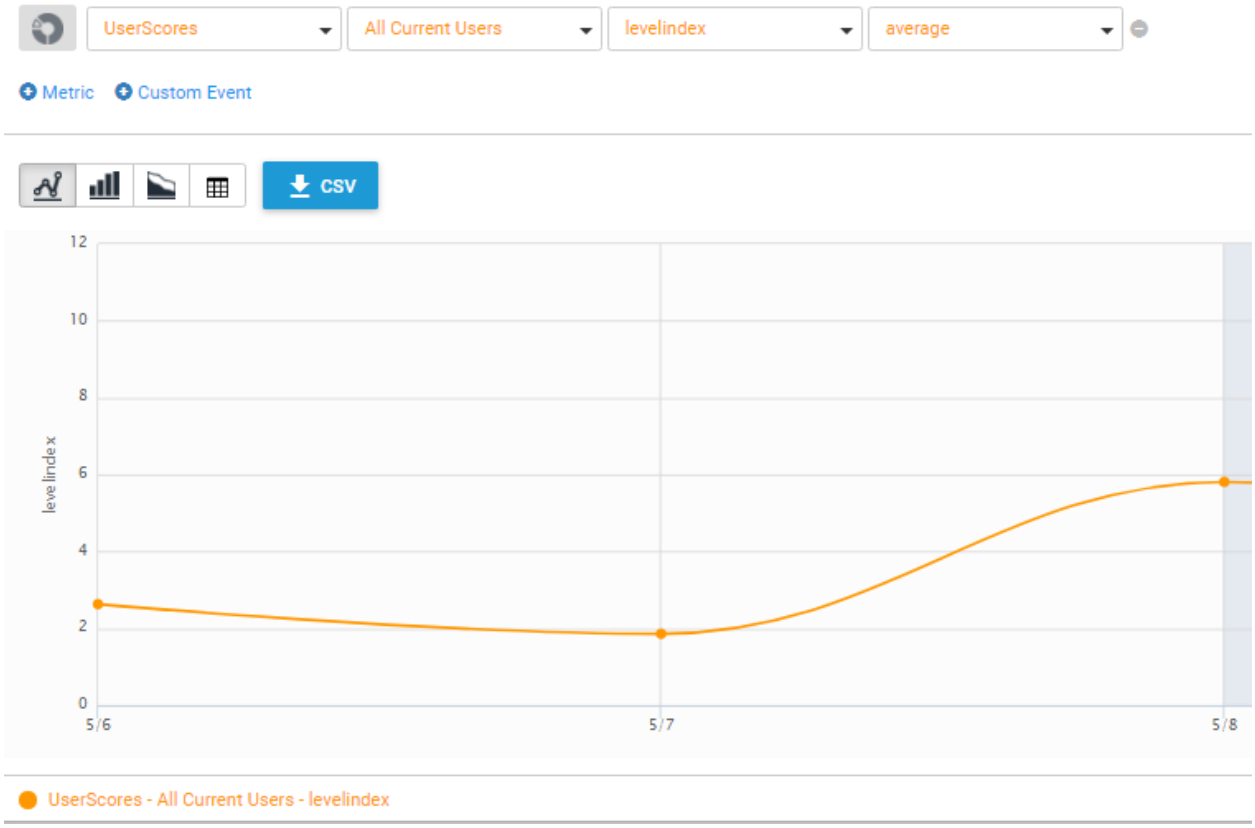
The chart below shows the daily play time, which we divided by the number of players to get the average. The analytics showed us they played an average of 24 min, 27.5 min, and 27.33 min over a three-day test (explained in detail in the evaluation section below). So overall, they played an average of 26.28 min, which matches up pretty well with their self-reported average of 25.12 min.



This next chart shows their average level scores over the three-day test, 13.46, 13.79, and 12.44 respectively.



The next chart shows what level difficulty they were playing at on average each day, 2.63, 1.86, and 5.81 respectively.



Learners were only required to play 15 minutes a day, so this indicates they were motivated to play longer than required. Their level scores increase and then decrease, but seem to correspond with the level difficulty they were playing at. The average level difficulty decreased for the second day and then increased significantly for the third.

We were also able to pull data on what costumes were purchased, but there were none that were purchased more than the others, and most of the ones purchased were the cheapest costumes, possibly because the test only lasted three days and they may not have had enough time to earn enough coins for the more expensive costumes.

Implementation Instruments

For Number Ninjitzu to be tested, we needed to get the game onto phones and tablets. We did this through an .apk file (Android package) for Android devices. Unfortunately, we weren't able to publish the game onto iOS devices remotely for the test. Testers had to download and install the files to their devices.

For Number Ninjitzu to be widely implemented, we will need to publish the app on the iOS and Android store so anyone can download the game. The game should work on all phones with the latest operating system.

One initial concern for this product was that learners would use the app as a game exclusively and avoid any math. We addressed this concern by ensuring that players can't progress in the game or receive any rewards without attempting to solve the math problems and answer many of them correctly.

Another worry is that students will take too long to solve the math problems. We ensure they try to move at a quick pace by basing certain rewards on the time it takes them to complete a level.

Another worry is that students will not be able to solve the math without a pencil and paper. To help this issue, we scaffold the learners by allowing them to write on the scrolls with the math problems as they would with a physical piece of paper. However, we eventually want them to move towards using only mental math to solve the problems. With practice, students should start forming shortcuts and the ability to do mental math without having to write anything down.

In the app stores, we will include a link that will allow customers to contact us for support. Customers will also be able to leave feedback in the form of reviews.

I piloted our product by finding participants in 1st-3rd grade who had access to a smartphone or tablet, in order to play Number Ninjitzu. They needed to understand basic mobile game technology in order to operate the app. They also needed to have the ability to solve math problems starting at a first grade level. I checked with their parents beforehand to make sure they had the required technology and ability to test.

The parents were provided with instructions on how to download the app, how often the children would need to play, and what questions to ask them after they played. (See the following for the instructions provided to the parents).

Thank you for your participation in this test! Since our product is still in the testing phase, you may run into bugs. We would love to hear about any issues you experience, so we can make our game better. This test will run from Thursday (5/6) - Saturday (5/8). Please text or call me if you have any questions.

Some quick notes:

- Although the game shows 16 levels, there are currently only 14 that are playable.
- The math difficulty increases with each level. Players can earn more money on higher levels, but they are welcome to keep playing at the lower levels if they don't understand the math in higher levels. Math runs from first to third grade.

Instructions

1. Before playing the game, please print out worksheet 1 according to your child's (or children's) grade (if they are older than third grade, just give them the third grade worksheet). The worksheet PDFs are attached in the email I sent. Time them for 60 seconds to see how many problems they can do. Please text me how many problems they completed and how many they got correct. Or you can just send me a picture of their worksheet and I'll figure it out.
2. Have your child play the game for at least 15 minutes a day (we are hoping they will want to play longer, but it's okay if not). See installation instructions. Please have them keep track of how long they play each day. You can text me this each day or report it on the form on the last day.
3. After they are finished playing on the last day (Saturday), print out worksheet 2 according to their grade and time them for 60 seconds again. Text me how many problems they completed and how many they got correct, or send me a picture.
4. Finally, please fill out this form at the end for each child that tested. You can copy the questions in the form and send them with the answers to me in an email. Or I am happy to interview your child over a phone call if you don't have time!

App Installation Instructions

Android Phone

- Go to settings, Security, Unknown Sources, then make sure “Allow installation of apps from unknown sources” is turned on (you can turn this back off after downloading our app)
- Click the link in your email, should start downloading
- Click install after it’s finished downloading
- Click open
- App should also be in your app library

Kindle Fire

- Click the link in your email
- Click download
- Click download anyway
- Will say Downloading file at the bottom of the screen
- When file is done downloading, click open
- Will say staging app, when this is done click install
- After it’s done installing, click open
- App should also be in your app library

End of test survey

Gender:
Age:
Grade:
Length of play (Day1, Day 2, Day 3):

Did you see any bugs or problems with the game?

What did you like about the game?

What didn’t you like about the game?

What would you add or remove to make the game better?

What are your top three favorite costumes?

Is this game more or less fun than other math games you have played? How is it different from other math games you’ve played?

Would you keep playing this game on your own?

Do you think playing the game helped your math skills?

Did the game make you like math more?

Evaluation Instruments

Stakeholders
Peter Rich is the main stakeholder involved in this project. He is interested in whether the game will increase math fluency and engagement for young learners. The IPT Department is also a stakeholder in the project, as they are funding it. They expect the game to be used for educational purposes.

Criteria for Success
The two main goals of this project are to increase early elementary students' math fluency and to do so in an engaging way. These two outcomes (fluency and engagement) guide the following evaluation plan.

Formative Evaluation
Formative evaluation took place throughout the game development process. In weekly team meetings, we discussed artwork, user experience, motivating elements, instructional progression and support, and overall gameplay. Additionally, we held informal playtests to see if the game was functioning well and to see what players liked and didn't like.

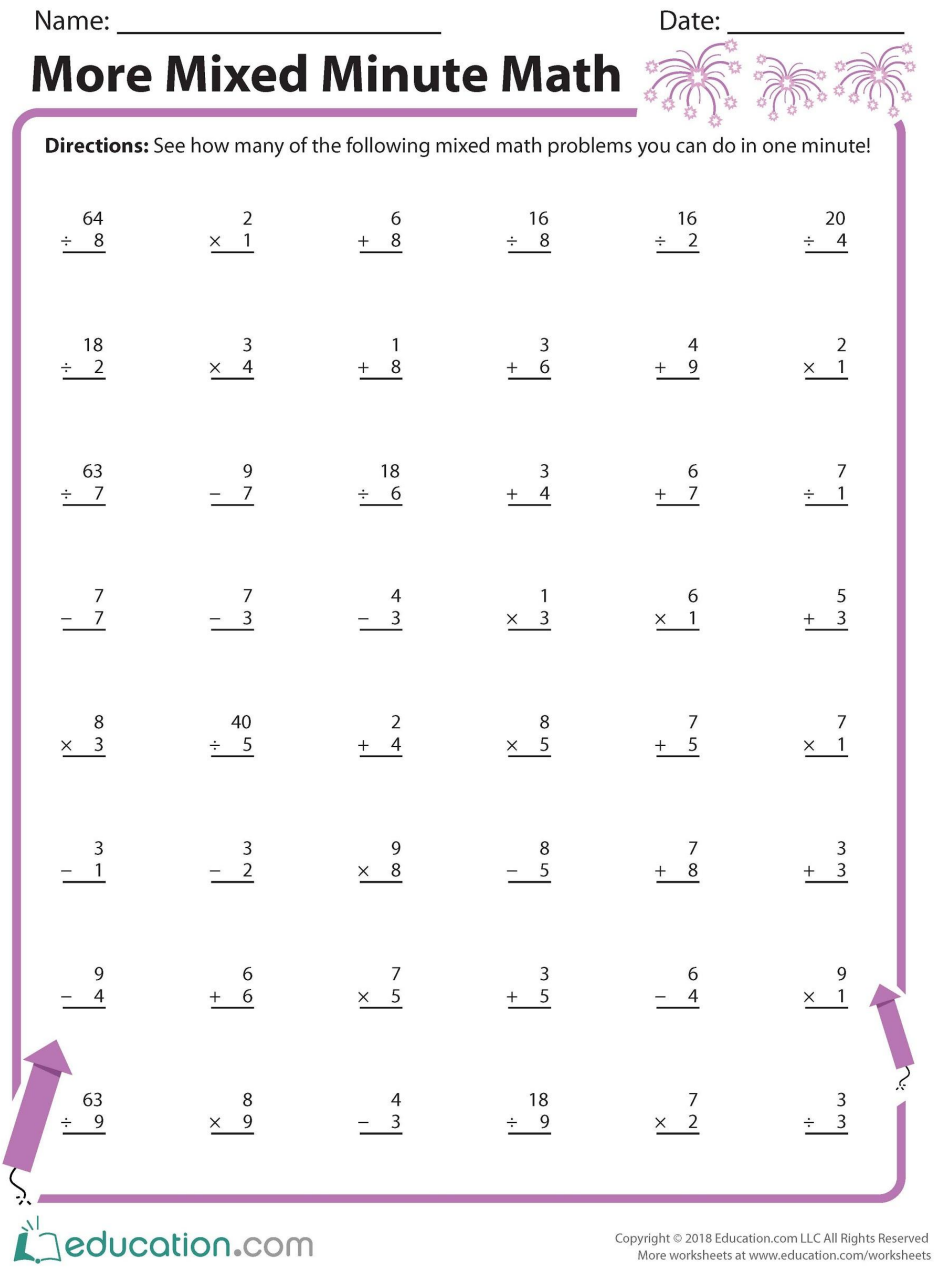
Evaluation Questions
The main evaluation questions I asked at each stage include:

- Is the game focusing on math?
- Will the game help learners improve their math fluency?
- Is the game engaging?
- Does the game help students develop a more positive view of math and their math ability?

Summative Evaluation
For summative evaluation, I looked at the data collected through the following quantitative and qualitative assessments and reviewed our learning analytics data to evaluate whether the project satisfied our learning goals. I decided the product would be considered successful if there was a learner increase in math fluency after playing the game, if learners reported largely positive views of the game, and if learners were motivated to play the game often.

Criteria 1: Math Fluency
In addition to collecting learning analytics, I assessed students' knowledge through a simple pre/post experience. To do this, I piloted the game with 14 young learners. Most of them were in the target age group (1st-3rd graders), but a few were a bit outside of it. This helped me evaluate whether learners achieved the goal of improved math fluency. The children chosen to test the game were given a worksheet prior to playing and were timed to see how many problems they could complete within a given time limit. The worksheet given was matched with their grade level and included all relevant arithmetic (e.g., the third grade worksheet included addition, subtraction, multiplication, and division). Then, the children were given the opportunity to play the game for three days. After trying out the game, students were given the same type of worksheet and timed in the same way to see if their math fluency improved. This second means of assessment (apart from collecting data straight from the game) also helped us see if the learning from the game translates well to traditional tests, like a physical worksheet.

The following is an example of the type of worksheet that was used to assess learners.



Name: _____ Date: _____

More Mixed Minute Math

Directions: See how many of the following mixed math problems you can do in one minute!

64 ÷ 8	2 × 1	6 + 8	16 ÷ 8	16 ÷ 2	20 ÷ 4
18 ÷ 2	3 × 4	1 + 8	3 + 6	4 + 9	2 × 1
63 ÷ 7	9 − 7	18 ÷ 6	3 + 4	6 + 7	7 ÷ 1
7 − 7	7 − 3	4 − 3	1 × 3	6 × 1	5 + 3
8 × 3	40 ÷ 5	2 + 4	8 × 5	7 + 5	7 × 1
3 − 1	3 − 2	9 × 8	8 − 5	7 + 8	3 + 3
9 − 4	6 + 6	7 × 5	3 + 5	6 − 4	9 × 1
63 ÷ 9	8 × 9	4 − 3	18 ÷ 9	7 × 2	3 ÷ 3

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Criteria 2: Learner Engagement

I used observations and interviews to see what players liked and didn't like about the game. I analyzed their feedback together with learner analytics to evaluate what motivates the learners to play the game more and what needs improvement. I discussed my findings with the team in weekly meetings and got their opinions on how to address the needed changes. We also got student feedback after administering the post-test to ask students what parts of the game engaged them the most, how the game compares to other games they've played, if they're likely

to keep playing the game, if they thought the game helped their math skills, and if the game made them like math more.

Qualitative data from the observations and interviews was reviewed, with the purpose of looking for common themes. I discuss my findings in the following section.

Evaluation Findings

Criteria 1: Math Fluency
Unity analytics showed level scores increasing a bit on the second day and then decreasing on the third day. This is affected by what levels users played (difficulty of the level and different levels having different top scores), so more testing and more detailed analytics would be needed to see if their level scores improved the more they played the game. This also seems to correspond with the average level difficulty they were playing at each day (when difficulty increases, scores decrease).

However, traditional academic measures revealed clearer outcomes. The pre/post worksheet test showed an average improvement of 23.72% (problems completed) and 24.55% (problems correct) on the worksheet taken after playing the game for three days versus the worksheet taken before playing. Three children didn't complete enough for the test and were taken out of the data.

Players self-reported how much time they played each day and it came out to 22 min, 21.91 min, and 28.64 respectively, with an average time played of 25.12 min a day. This was just slightly under the usage analytics we collected automatically.

	Correct 1	Completed 1	Correct 2	Completed 2	Day 1 Time	Day 2 Time	Day 3 Time
Player 1	7	13	7	13	15	15	15
Player 2	14	14	12	12	15	15	15
Player 3	31	32	41	41	20	15	15
Player 4	18	18	25	25	30	25	25
Player 5	12	12	18	18	30	30	30
Player 6	20	20	21	22	30	30	80
Player 7	42	42	52	52	30	16	25
Player 8	36	36	45	45	20	20	20
Player 9	28	28	36	36	15	15	15
Player 10	16	17	25	25		45	60
Player 11	8	11			15	15	15

Criteria 2: Learner Engagement
The following are takeaways from the feedback survey I administered after participants tested the game for three days. I format the takeaways according to the questions I asked.

Did you see any bugs or problems with the game?
There were some really good bugs reported, mostly to do with the game freezing at a couple places and also one math issue, where the answer was five numbers, but they could only type in four. They also complained about the comic being hard to read, but this is because our artist hasn't finished all of the comics and some of them are still sketches with handwriting.

We intend to go through and resolve all of the bugs, as well as finish up the art for the final version.

What did you like about the game?
Things players liked about the game included being able to choose their characters, earning coins and buying costumes in the shop, the cool art in the game, collecting scrolls, the adventure and storyline, the comics, the challenge of getting stars, being able to run and jump, the flips, being able to draw on the scrolls, and the math problems. These are illustrated by their following qualitative responses:

- “I just got addicted. I couldn't help it. It was just like I need to play more.”
- “I really like the store and the different outfits and I liked the times tables and division. It's cool to have an adventure and collect scrolls and it's a fun challenge to try and get three stars and I loved the comic a lot. I loved the flips.”
- “It has a storyline and you can actually make progress and earn coins. I like the characters and the costumes and the art.”
- “It was so fun because it was like a video game.”
- “I like the shop and all the cool things that you can get. And I liked the scrolls, they look really old and it's cool. I like how the crane flies and drops the scrolls.”
- “Being able to choose characters and that you can get coins. Nick was my favorite character.”
- “I liked the math problems.”
- “The practice before the levels makes solving the problems so much easier.”

We were pleased with this feedback. The things we hoped would entertain and motivate players are the same things they mentioned. I was glad to hear that the pre-level practice (i.e., help with knowing how to do the problems coming up in the level and explaining the mental math strategies) was helpful, indicating that the just-in-time instruction was a useful strategy for educating while maintaining engagement.

What didn’t you like about the game?
There were also a number of things to improve about the game. Most of the feedback had to do with game bugs. However, players also mentioned the math being too hard and the levels being too similar. Additionally, some kids didn’t find the costumes or the comics and another was frustrated with the characters moving too slow (they run if you double tap, which is in the tutorial but only briefly). Another was confused about how to get on the roof.

This feedback tells me that we need to make the interface clearer and also explain more clearly how to play the game or make things more intuitive.

- “The levels are too similar.”
- “The comics weren't super accessible.”
- “On the first level it was really confusing on how to get into the roof “

What would you add or remove to make the game better?
Things players would want to add to the game include flying (this is in one of the later levels), fighting monsters, more big jumps, a swimming level, more flips and moves, more characters, and different level scenery.

- “Add power ups or different scenery/backgrounds.”
- “You should have more flips and moves as you become a ninja.”

- The only things they said to remove are the math and the climbing, because it was difficult.

This is great feedback and I definitely think we can add more fun and surprising things to the final version of the game. We also need to work on making the climbing move more intuitive.

What are your top three favorite costumes?
There weren't any repeat costumes in the feedback, but I think if they would have played longer and unlocked the more expensive and "cooler" costumes (they can't see them unless they purchase them) then some favorites would emerge.

Is this game more or less fun than other math games you have played? How is it different from other math games you've played?
Eight said it was more fun, two said it was the same, and one said it was less fun than one game they've played.

- "Way funner by a long shot."
- "It's fun (it's equal fun to other math games)."

Would you keep playing this game on your own?
Out of the children who took the survey, nine said yes, one said probably, and one said maybe.

- "Yes (she literally asked if she was able to keep playing)."
- "Yes I already want to."

Do you think playing the game helped your math skills?
Five said yes, five said no, and one said kind of.

Did the game make you like math more?
Eight said yes, three said no. My cousin who "hates math," said "Absolutely not!" but she did enjoy the game. A few kids mentioned that they already really like math.

Outcomes

Again, the two main goals of this project were to increase early elementary students' math fluency and to do so in an engaging way.

The initial evaluation suggests that these goals are being positively met after only three days of playing the game. However, these are limited by the sample size and method. More testing and more specific analytics with a larger, more diverse, group are needed in order to see if Number Ninjitzu reliably improves fluency and to see if this fluency is retained over time.

Evaluative feedback leads me to conclude that this project is a success in terms of engagement. The testers played on average almost double the amount of time they were required to play, which means they enjoyed playing the game and were motivated to keep playing it. The majority of testers really liked the game and said they would keep playing it on their own. The elements we hoped would be fun and engage players such as buying costumes, earning stars and comics, etc., were all mentioned in the things they liked about the game. Most of the testers also said this game was more fun than other math games they've played. I am excited to take their feedback and continue to improve the game until it is completely polished and ready to publish to the app stores so more kids can play it.

Budget and Timeline

Planned Budget

The following image shows an estimated budget for completing the project. As the project manager, I only calculated five hours a week for my work, since I will not be getting paid for the hours I put into the project that don't include game development.

Estimated Budget to Complete Project

	Project Manager	Programmer	Artist
Wage	$18	$15	$15
Hours per Week	5	9	9
Weeks until completion	25	25	25
	$2,250	$3,375	$3,375
	Total:	**$9,000**	

Extra Semester Budget

The following image shows an estimated budget for the additional semester the project is taking.

Estimated Budget to Complete Project				
	Project Manager	Programmer	Programmer	Artist
Wage	$18	$17	$17	$15
Hours per Week	5	9	9	9
Weeks until completion	15	15	15	15
	$1,350	$2,295	$2,295	$2,025
	Total:	**$7,965**		

Timeline

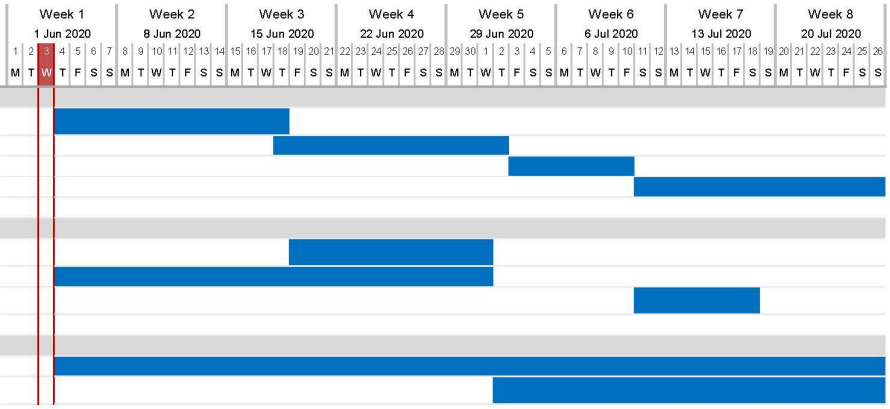
The following image shows a proposed timeline for completing the project. Unfortunately, the project ended up taking one more semester than anticipated. We ended up hiring an extra programmer to help get the work done.

Number Ninjitzu Project Schedule

Gantt Chart Template © 2006-2018 by Vertex42.com.

Schedule Start Date 6/4/2020 (Thursday)
Project Lead Abby Hull

WBS	TASK	LEAD	START	END
1	**Development**			-
1.1	Complete Playable Level	Rory	Thu 6/04/20	Thu 6/18/20
1.2	Complete All Levels	Rory	Thu 6/18/20	Thu 7/02/20
1.3	Complete Mini Game	Rory	Fri 7/03/20	Fri 7/10/20
1.4	Complete Interface	Rory	Sat 7/11/20	Sat 8/01/20
1.5	Fix Bugs	Rory	Sun 8/02/20	Tue 9/01/20
2	**Instruction**			-
2.1	Pilot Test Level with Learners	Abby H.	Fri 6/19/20	Wed 7/01/20
2.2	Complete Math Help	Abby H.	Thu 6/04/20	Wed 7/01/20
2.3	Pilot Test Mini Game with Learners	Abby H.	Sat 7/11/20	Sat 7/18/20
2.4	Pilot Test Full Game	Abby H.	Sat 8/01/20	Tue 9/01/20
3	**Art**			-
3.1	Finish Comic	Abby S.	Thu 6/04/20	Sat 8/01/20
3.2	Create Interface Elements	Abby S.	Thu 7/02/20	Sat 8/01/20



The following table shows planned completion dates from the timeline versus actual completion dates. This really highlights how wrong we were about how long this project would actually take.

Task	Planned Completion Date	Actual Completion Date
Complete Playable Level	6/18/2020	12/15/2020
Complete All Levels	7/2/2020	2/26/2021
Complete Interface	8/1/2020	2/23/2021
Pilot Test Level with Learners	7/1/2020	1/2/2021
Complete Math Help	7/1/2020	2/1/2021
Pilot Test Full Game	9/1/2020	2/27/2021
Finish Comic	8/1/2020	Not finished
Create Interface Elements	8/1/2020	2/23/2021

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