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Laine Tatu

# EDUCATIONAL MOBILE GAME

## Math Jump, from concept to a published title

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# EDUCATIONAL MOBILE GAME

The innovative use of gameplay mechanics to drive effective learning is a hot topic despite the scarcity of practical examples. The game produced in this thesis is an innovative attempt to develop an engaging multiplication math game for kids aged 7 to 12.

This thesis presents an overview of game theory, gamification, and business opportunity as the reasoning for the development of Math Jump, a game idea generated by the educational game company NordicEdu. A multitude of game development tools were used to develop a minimum viable product for the purpose of learning about the mobile educational game market.

The iterative design and technical process is documented from different aspects with practical examples provided. The game also went through a field test which resulted in some feature polishing before release.

The outcome of this thesis “Math Jump” was published in the most common digital distribution platforms in the early spring 2013.

KEYWORDS:

game, gaming, gamification, learning, mobile, game design, business models, game theory

OPINNÄYTETYÖ (AMK) | TIIVISTELMÄ
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# OPETTAVAINEN MOBIILIPELI

Pelillistäminen on globaalisti kiinnostava kehitysalue, vaikka käytännön onnistuneita ratkaisuja on vähän. Pelillistämisellä katsotaan olevan monia hyötytarkoituksia perinteisen teollisuuden ja opetuksen alalla. Tämän mahdollisuuden innoittamana, opinnäytetyön toimeksiantaja NordicEdu Oy lähti kehittämään innovatiivista opetuspeliä 7 – 12 –vuotiaille lapsille.

Opetuspelin taustatutkimuksena luotiin katsaus perinteiseen peliteoriaan, pelillistämiseen ja liiketoimintamahdollisuuksiin aloittavan yrityksen NordicEdun näkökulmasta. Pohjatyöstä ja idean kehittelystä siirryttiin tuottamaan minimiversiota pelituotteesta, jolla voidaan mitata opetuspelin markkinapotentiaalia digitaalisissa jakelukanavissa ja mahdollisesta tuottaa rahaa.

Kehityksen aikana pelin asteittainen luova ja tekninen kehitystyö dokumentoitiin eri näkökulmista käytännön esimerkkejä käyttäen. Peli toteutettiin Unity3D-pelimoottorilla, joka on pienyrityksille tehokas työkalu interaktiivisten sisältöjen luomiseen alustariippumattomasti. Peliä myös koekäytettiin kohderyhmän kanssa, jonka palautteen perusteella peliä hiottiin ennen julkaisua.

Opinnäytetyön tuloksena syntynyt ‘Math Jump’-matematiikan opetuspeli julkaistiin yleisimpien mobiililaitteiden digitaalisissa jakelukanavissa alkukeväästä 2013.

ASIASANAT:

peli, pelillistäminen, oppiminen, mobiili, pelisuunnittelu, liiketoimintamalli, peliteoria

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# LIST OF ABBREVIATIONS AND TERMS

| | |
|---|---|
| Android | Linux-based operating system for mobile devices. |
| Appstore | Digital application distribution platform for Apple devices maintained by Apple Inc. |
| Bitbucket | Web-based hosting service for revision control systems |
| BoostTurku | Student-based network for young entrepreneurs and entrepreneur-minded people sharing knowledge among the universities of Turku. |
| Freemium | Business model where the product or service is offered free of charge. Advanced features can then bought inside the game, which are called in-app-purchases. |
| Gamification | The use of game-thinking and game mechanics in a non-game context in order to engage users and solve problems. |
| Google Play Store | Digital application distribution platform for devices running the Android operating system developed by Google. |
| Mercurial | A cross-platform, distributed revision control tool. |
| MVP | Strategy used for fast and quantitative market testing of a product or product feature. |
| Premium | Business model where the core product costs, in favor of higher profit margin on a lower sales volume. |
| Steam | Digital distribution, digital rights management, multiplayer and communications platform developed by Valve Corporation |
| TortoiseHg | Revision control client based on Mercurial. |
| Twitter | Online social networking service and microblogging service that enables its users to send and read text-based messages of up to 140 characters, known as "tweets" |

# 1 INTRODUCTION

Building and publishing a game might sound like a easy task but after the initial enthusiasm, it becomes a daunting journey of iterations and self-doubt. In the game development industry, small game companies have a chance to be viable by distributing their games in the new digital distribution platforms, such as Appstore, Play Store and Steam. It is common for a game company to produce several games that fail in giving their return of investment. However, big hits can stand out and cover the costs of the failed games.

Games are entertainment and they should thrive to create fun and engagement. The game made in this thesis twists that fact, by bringing in an educational aspect that will benefit the player in real life situations while maintaining the entertainment factor as high as possible. The game ‘Math Jump’ is an educational multiplication game for young children. It is free to play and it is developed to utilize the new novel features found in modern smart phones and tablet-devices.

The outcome from this thesis was not clear in the beginning of the project. This is why iterative design principles were used in creating the game with a set of ideals. [1] Game development utilizes a multitude of skills varying from 3D, animation, design, graphics, sound, storytelling, coding to producing. Every aspect was applied to the game.

This thesis is split into four thematic parts. First part is the background for the reasons leading to the development of this game. Secondly, a brief game design theory is presented to lay the ground for the development of the game in the third part. Lastly, the game is published on the Appstore and the Google Play Store.

# 2 BACKGROUND INFORMATION

Using games to nurture education and useful skills has been a rising topic in the games industry. In the author's case, it was the summer of 2011 when words turned to actions as a startup-company now known as NordicEdu attended the Summer of Startups entrepreneurship-incubator program by BoostTurku Entrepreneurship Society. The result of this thesis was the second published product for NordicEdu.

Skills learned by playing games have little use in the working life apart from so-called soft skills, which are hard to quantify. Soft skills include traits such as teamwork, leadership, communication and negotiation. [2] Math Jump attempts to bridge this gap and analyze the results.

## 2.1 Minimum Viable Product

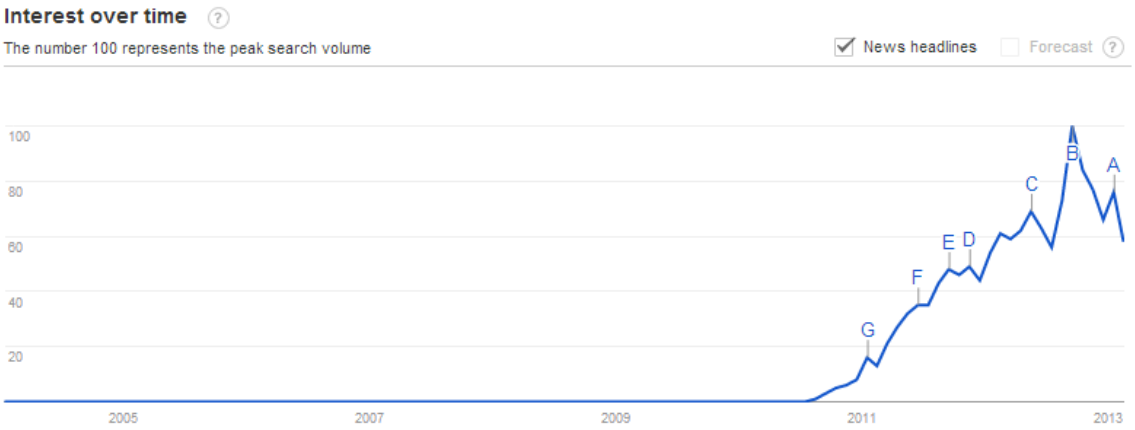
NordicEdu is benchmarking the interest for educational mobile games with the Minimum Viable Product (MVP) approach. We are trying to maximize the information learned about the customer with as little money as possible.

> "An MVP is not a minimal product; it is a strategy and process directed toward making and selling a product to customers. It is an iterative process of idea generation, prototyping, presentation, data collection, analysis and learning. The process is iterated until a desirable product-market fit is obtained, or until the product is deemed to be non-viable." [3]
>
> - Eric Ries, author of "Lean Startup" ideology

Math Jump was released via digital distribution platforms when the game core mechanics worked, it had crude but consistent graphics and basic sound effects. Once released, NordicEdu is in the process of tracking download numbers and promoting it virally through Twitter, Facebook and possibly through e-learning mailing lists. If the game receives a fair amount of downloads (over 100 a day) NordicEdu will continue updating the game and applying monetization. Monetization is the process of creating revenue from a product in different ways. [4]

## 2.2 Gamification

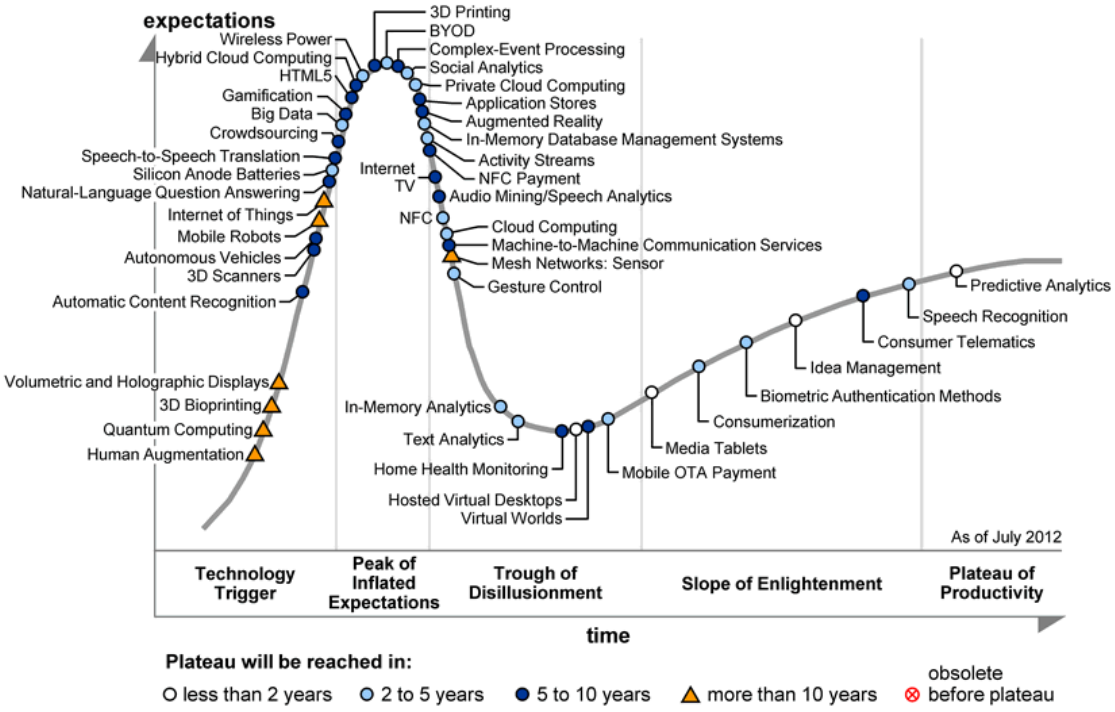
The idea of using game mechanics, such as goals, fantasy and challenges to drive engagement in non-game applications has come be known as “gamification”. [5] Gamification is very new and gathers interest from different fields such as marketing and enterprise, where sales personnel could be engaged in a light-hearted competition for the highest sales or executives could be motivated to hold more remote meetings via Skype to avoid unnecessary flying or driving.




Picture 1 Gamification in Google Trends at the time of 5.2.2013

The word ‘gamification’ is not found in the English dictionaries yet. [6] But it is believed that soon it will be. A good comparison is the English verb ‘google’, which was added to the Oxford English Dictionary on June 15, 2006. [7]

By 2015, more than 50 percent of organizations that manage innovation processes will gamify those processes, according to Gartner, Inc. [8] Gamification has also made its way to the Gartner hype cycle, which is a graphic representation of the maturity, adoption and social application of specific technologies.




Picture 2 Hype Cycle for Emerging Technologies, 2012 [9]

Gamification can be seen nearing the peak of inflated expectations and is estimated to have mainstream adoption in 5 to 10 years. Considering how the concept has been popularized from 2010, we can say it is developing at the estimated pace.

## 2.3 Hard and Soft gamification

To better communicate what gamification means, it is useful to separate it to two categories: soft and hard gamification. [10] Soft gamification lends game mechanics from games to drive engagement in websites, social media and physical exercises. Badges, coins, achievements, avatars and progress bars have found their way to many websites.


Figure 1 Human desires and game mechanics. [11]

Figure 1 illustrates the interaction of basic human desires and game play. The green dots signify the primary desire a particular game mechanic fulfills, and the blue dots show the other areas that if affects. This is prominent in soft gamification.

Hard gamification is creating an actual game around an idea that is a non-game to begin with. Like in the game made in this thesis, the player will learn math, but that is not the main goal of the game from the player's perspective. Some games might do education gamification so well the player will not even notice that he/she is learning important skills. For example, racing games are bound to teach one how to drive a car if they play at lot of realistic rally games.

## 2.4 Opportunity

Digital distribution platforms for mobile devices will see high growth in the next few years as worldwide smart phone sales continue to soar higher. [12] South Korea is a prime example of this. The government has decided make all the text books in primary school all digital by the year 2015. [13]

The US market for mobile learning products is estimated to be double in 2015 compared to the year 2010. [14] The US Game-based Learning market reached $231.6 million in 2010. The growth rate is 12.3% and revenues will reach $413.2 million by 2015. [15] For comparison, the whole of US video game industry is valued at $76.1 billion in 2013. A Finnish game company needs to be international to tap these markets and to be profitable.

# 3 A BRIEF INTRODUCTION TO GAME THEORY

> “A game is a series of interesting choices”
>
> - Sid Meier, Firaxis Games

“A game is a type of play activity, conducted in the context of a pretended reality in which the participant(s) try to achieve at least one arbitrary, nontrivial goal by acting in accordance with rules.” [16] This definition by Ernest W. Adams is not all-inclusive and it may even prove to be impossible to have such a definition, at least for a continued time. But it is a good definition for practical purposes nonetheless.

The theory of games is constantly argued. The debate is the strongest when discussing video games in particular. This field of entertainment, which is rapidly pioneering new ways of entertaining people, often lacks a clear common language when discussing video games in a professional context. Game industry professionals struggle to debate and communicate ideas, even more so with clients, publishers and marketers from different fields. This is partly because game design is a relatively new field of science and it has not been on the focus of much research.

A highly respected game designer, Jesse Schell argues that the gaming industry’s lack of standardized vocabulary is not such a big deal, even if it slows down the designing process, but on other hand it makes designers do a better job because they have to communicate and think a little further. [17] The multidisciplinary skills needed for making games require new words and new meanings for them. This is also why non-english speaking countries borrow a lot of the game design vocabulary from the English language. It is also still worth noting, that in the eyes of people from different fields, games have to constantly justify their existence on par with art, movies and music.

## 3.1 Play

> Work consists of whatever a body is obliged to do. Play consists of whatever a body is not obliged to do.

- The Adventures of Tom Sawyer by Mark Twain[18]

Children are great at playing. It is how they learn to avoid dangers and live in our community. The best approach to surviving different situations is to imagine them beforehand and play them out with or without our friends and using toys as representations of objects. We grownups just have a different name for it: simulation. What sets simulation and play apart is that play is associated with fun and simulation with work. The ideal situation is that working is fun and this is what gamification is trying to achieve.

Another good disparity derives from the entertainment industry. Play is a participatory entertainment and for example, books or films are not. Every game is interactive meaning the outcome or the means to the end can be affected. Play enables different choices and experiences within the game rules. Creatively bending the rules in a game can be very exciting. For example; to enable risk-taking, this must be followed up with a reward if the player succeeds.

## 3.2 Pretending

Players of a game agree to a certain level of pretension, this is often referred as the “magic circle”. The magic circle sets the boundary between ideas and activities that area meaningful in the game from those that are meaningful in the real world. [19] There is a possibility of mixing the real world with video games, but this happens rather seldom and presents itself through game addicts as indirect behavioral harmful actions. The game made in this thesis includes real life skills in its magic circle and affects the player positively in the form of learning math more effectively. In Math Jump, the actual boundary of the magic circle should be always very obvious.

## 3.3 Goal

Goal is the attribute in games that is the most controversial. Games like The Sims or Minecraft lack a clear goal. This is because the gameplay is mostly creation and it is up to the player’s creativity and ambition to define the goals.

The goal is often understood as a victory condition, but in the aforementioned games you might even want to consider killing your avatar as a goal. There is no clear point system to tell you what “you are supposed to do”.

Old arcade games usually had an unattainable goal so that the arcade machines could gobble as much of the player’s money as possible. The games were mostly based on getting the high score, an easily comparable number between players. Competition between your friends boosted the meaning of the goal even further.

Today many of the popular console games come up with new goals sometimes even to the point of exhaustion. The player is always reminded what to do next and the game assumes you have an attention span of a few seconds. To top it off, you are bombarded with achievements and additional prizes all the time. Clear goals are considered good game design, but there is a golden mean not taken in many cases.

### 3.4 Rules

Rules are created in advance by a game designer and rarely change significantly during the game. Every player must accept the rules before starting the game and for example, often in children’s play, there are a lot of unwritten rules. Good game design does not make the player read through a lot of instructions, but presents rules through gameplay without disturbing the learning curve much. In single player video games, the computer has the perfect judgment system and the player has only small ways to affect the rules, like setting a very generic difficulty setting. Once you introduce multiple players, additional rules can be agreed upon at any time.

Rules have a great effect on the amount of luck in a game. A game of perfect information such as chess has no probability or leeway in its rules, so it does not have an element of luck. The losing player might say that the opposing player was lucky but that is only between the players. Snakes and Ladders is a board game based entirely on luck but it still has very clear rules on how you

can proceed with your game piece and what happens if you get eaten by a snake. [20]

### 3.5 Meaningful play

Meaningful play in a game emerges from the relationship between player action and system outcome; it is the process by which a player takes action within the designed system of a game and the system responds to the action. The meaning of an action in a game resides in the relationship between the action and the outcome. [21]

In this thesis, a variety of methods were used to create meaningful play. These include rules, goals, pretending and play. The use of sound, aesthetics, game mechanics and dynamics, urge and instant feedback support these concepts further.

# 4 PREDEVELOPMENT AND TECHNOLOGY

As an engineer, one is bound to have a game idea that presents a great coding challenge so one can bathe in hacker pride or lose interest in the whole project because “somehow” the game started to become too complex. The same applies to an artist, battling with the problem of focusing too much on aesthetics. But as a game designer one must create a harmony between all the components so that no one aspect is overwhelming. Vice versa, not one component can be removed without breaking the whole. Angry Birds is a grand example where every component of the game feels necessary and you cannot really define how the game could be any better.

Design is making sense (of things) [22] The best mobile games make sense of things as fast as possible. When starting to play a game, everything must be taught as efficiently as possible. Making the player read through extensive tutorials quickly alienates many gamers and the game is left unplayed. Try the famous “mom test” [23] that contributed PopCap to become a hugely successful company. They are great testers, because we are still living in a time where most moms do not play much mobile games. Every ingame icon should be as self-explanatory as possible and fit cultures and customs around the world.

## 4.1 Player-Centric Approach

A game designer’s main goal is to entertain the player, all other motivations are secondary. [24] As this project brings in a learning aspect to the game, entertainment value is bound to suffer. Mihaly Csikszentmihalyi’s idea of a flow channel is apparent in the best of games. [25] Flow is experienced when perceived opportunities for action are in balance with the actor’s(player’s) perceived skills. Entertaining games always maintain a good flow by balancing challenge with the skill of the player.

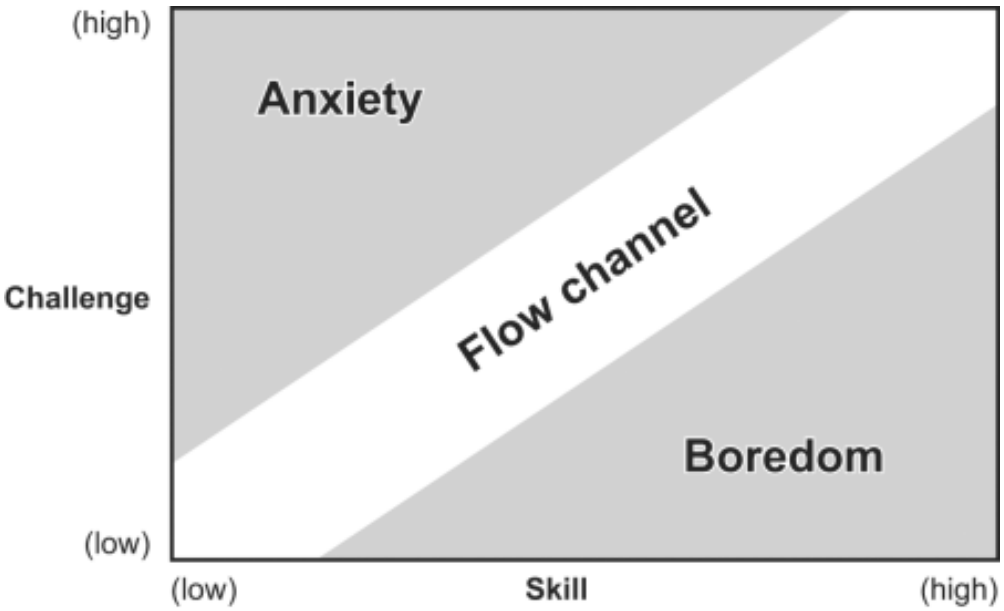



Figure 2 Theory of flow[26]

The learning aspect of the game will potentially create a lot of fluctuation between boredom and anxiety inside the flow channel of Mihaly's theory, so equalizing measures were taken during the development of the game.

Two game design rules are critical for a successful game: *You are not your player* and *The player is not your opponent.* The first one requires you to imagine what it is like to be your player, even if that person is someone very different from you. The latter one reminds you about the responsibility to entertain and that there are many ways to entertain a player. [27]

## 4.2 Concept Design

> "The secret to creativity is knowing how to hide your sources"
>
> - Albert Einstein

Albert paints a bleak picture with his words, but there is truth to the statement. The consumers are mostly playing copies of copies of games and true innovations are far and few. That is why creativity is an active, not a passive, process. A designer should make a habit of scribbling down ideas or pictures

whenever inspiration strikes. Inspiration can strike whenever; it can be a feeling or a deliberate action to promote it.

A good practice is also to force oneself to write down 20 game ideas in 5 minutes. Creativity often requires entering discomfort-zone and letting the mind flow. The inspiration for the game in this thesis came from the effortless control scheme of using tilt sensors and accelerometers found in almost every new mobile phone.

### 4.3 Idea

To take the idea further, it is best to start with describing what the player is doing. The theme and the settings can be thought of a bit later. Concept art, a pitch and iterating should start as soon as possible. What came to be Math Jump was pitched with this initial description.

> “You control an object, a robot or something that is bouncing on a surface. You can control the object horizontally by tilting the phone. Every subsequent bounce will make the ball bounce higher until it is about to reach the top of the screen. The ball displays a number and on top of the screen there are two goals. Each goal displays a different number. On the bottom of the screen is a fourth number which is the sum you have to make out by multiplying the number in the player ball with the correct number in the goal. This check happens when the ball on its final bounce, travels through a goal and lands on another platform higher than the previous. And the whole thing starts again.”

The usual feedback was: ”I don’t see the fun in that” or ”That has been done already and there is nothing unique about it.” Getting feedback is invaluable, be it negative or positive. One cannot really know what the outcome of a new game will be, but it starts somewhere and creating a constant feedback loop will speed up development.

### 4.4 Essential Experience

As a game designer trying to design an experience, the goal is to figure out the essential elements that really define the experience, and find ways to make them part of the game design. [28]

What Math Jump set out to convey through its gameplay is a sense of continuous accomplishment, urge and purpose. The sense of purpose is built by making right answers feel as good as possible and they give the urge to perform better through accelerating gameplay mechanics. The scoring system supports urge and right answers, making the player enter a state of flow more easily.

### 4.5 Focus Audience

Math Jump was developed for a certain target audience, with business in mind. It was important to understand the profile of both the downloader and the user of the game. Thus, two audiences were defined, to the best of NordicEdu's knowledge

#### 4.5.1 The Downloader

The typical downloader is a 20-40-year old mother or a father who is interested in technology and games. He or she owns a smart phone and plays games with it and sees several benefits of entertainment software. Sixty-eight percent of parents believe that gameplay provides mental stimulation or education. [29]

#### 4.5.2 The Player

The typical player is a 7- to 11-year-old kid, who likes to play games. Kids in the UK and US start learning multiplication in this age. [30][31] The kid might have his/her own smart phone and about third of the kids in that age group had a mobile phone in 2009. [32] The player is more probably a boy and likes competition between his peers. The player uses his dad's or mother's smart phone for gaming if he doesn't have his/her own and he/she still likes cartoons and funny characters in them and is prone to have a strong emotional connection to a fictitious character.

### 4.6 Established fundamentals

For the purposes of the game made in this thesis, a basic look at game theory was established and using that, a game idea was developed. The next step was

to evaluate the technology and iterate to find the fun and purpose in the game idea.

## 4.7 Unity3D

Unity3D is a game development tool for Microsoft Windows and Mac OS X and the games developed with it run on Windows, Mac, Xbox 360, Playstation 3, Wii, iPad, iPhone, Flash and Android-devices. It is a visual editor that supports C#, Javascript, Boo script, popular 3D-file formats and common audio file formats. [33]

To develop for mobile, a license that enables building the games on to Android devices was bought. The rapid prototyping tools included helped quickly observe and debug gameplay.

## 4.8 Test Device

A Samsung Galaxy S GT-i9000 [34] was used as the test bed smart phone for this game project. The main features of the phone are as listed:

- Super AMOLED 4.0” Display with 480 x 800 Resolution
- Samsung S5PC111 (Hummingbird)—SGX540 + Cortex-A8 CPU
- Android 2.3.3 Operating System
- Tilt sensor and accelerometer

The feature that restricts the game design most is the aspect ratio of the display and the ones that enrich it the most are the tilt sensor and accelerometer. Humans are used to receiving information with their eyes in a kind of a “landscape aspect ratio”. The display forces the game to make the best use of the portrait and landscape aspect ratios. Math Jump uses a portrait orientation, because most of the game objects only move or appear to move vertically.

Tilt sensor and accelerometer enjoy a certain level of novelty, because they are a new hardware feature in smart phones and many of the games out there do not make much use of them yet.

## 4.9 Version Control

Mercurial and TortoiseHg was used for version control for the game. Mercurial is a free, distributed source control management tool and TortoiseHg is a graphical interface tool extension for Mercurial. Unity3D supports external version control by providing a .meta –file for every asset of the game. The .meta –file, which is basically a text file, includes all the information that Unity3D needs to know about the asset without needing any existing project settings. Mercurial supports the most common version control functions such as revision control, file tracking, comprehensive merging tools and off-site repositories. The version control repository was hosted at Bitbucket.org.

# 5 DEVELOPMENT

A skilled game designer starts prototyping as soon as possible with whatever tools are fit for that. [35] Board games contain a lot of parts that can be useful in early prototyping. It can also help to cut representations of objects from paper and play with them. These primitive tools should be used to establish a state of playing a game as close to the actual desired gameplay. It is almost always faster to gain knowledge about the game mechanics this way than just starting to code the game from the start. This approach also applies to the aesthetics of the game in the form of concept art and mood boards.

Games that include physics as an important game mechanic are hard to simulate with primitive tools. Luckily, in the past years, game development tools have matured to the point where they might even include their own three-dimensional physics engine. The game development tool chosen for the game project supports physics, real-time shadows, visual design and a multitude of devices and software.

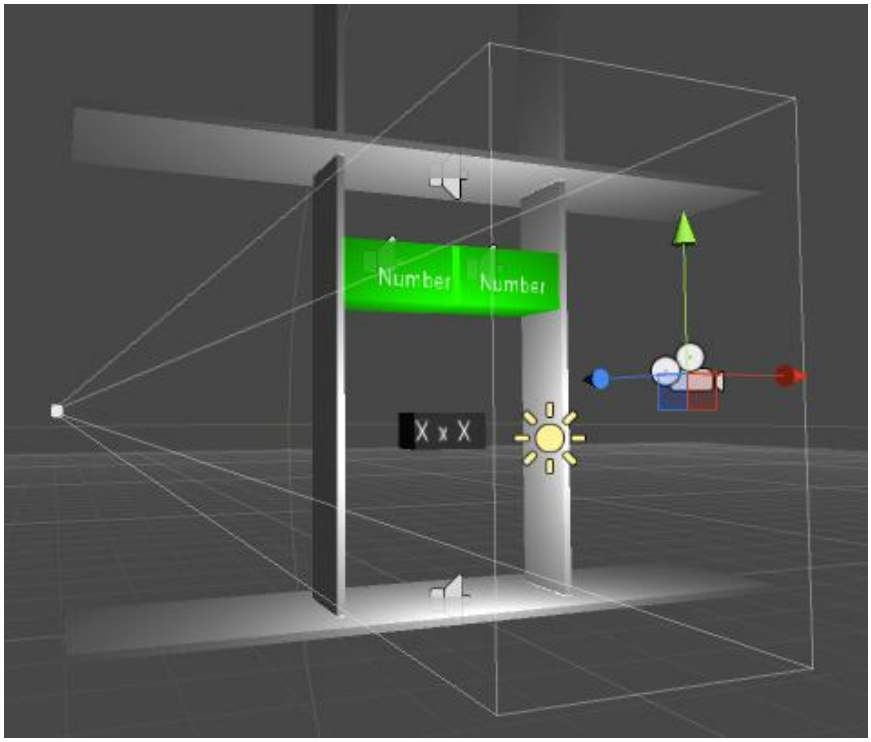
## 5.1 Game Core

A game core is an artificial system. A basic set of functionality that produces actions which the player starts to perceive as gameplay. The core rules of the game almost never change during the game. Math Jump has these core rules:

- The player is always in control of the avatar
- The avatar is controlled by tilting the phone
- There are always two different answers to the presented multiplication problem
- The multiplication problems and platform positions are always randomly generated
- The gravity is always the same
- You get points for answering correctly
- The game ends when you answer incorrectly a certain number of times

## 5.2 Implementation of the Game Core

Since the game core mechanics of Math Jump rely heavily on physics, it was wise to start iterating the game idea early in Unity. A set of objects was created to represent the player, goals, floor and numbers. Every object in the game inside Unity is referred as a GameObject, which is a container for Components. A GameObject always contains a component called Transform, which stores the position, rotation and scale of the GameObject. GameObjects can have many different components and users are free to create their own components.




Picture 3. A screen capture from the editor view in Unity.

The aforementioned set of game objects are presented in the picture above, along with the camera and a light illuminating the objects. Different Collider components play an important role in the physics engine of Unity. The black box is the avatar the player controls and it contains a Rigidbody and Sphere Collider components that enable it to be affected by gravity and collide with other similar GameObjects. The floor contains a Box Collider and also an Audio Source component indicated by a little speaker-icon. When the avatar collides with the floor it produces a sound.

Just under the top of the screen, two green boxes represent the goals with their numbers being generated when the actual game starts. The goals' Colliders serve as triggers for checking the result of the multiplication problem when the avatar passes through them and plays a sound depending if the multiplication problem is correct or false. The roof serves also as a trigger to generate a new multiplication problem once the avatar passes it, but after that it becomes solid so that the avatar keeps on bouncing and essentially the whole process is repeated.


Picture 4: Gameplay screen capture with the avatar in mid-air

The gameplay picture shows the view from the camera in the editor. The projection setting for the camera is orthographic. The same object will appear to be the same size regardless of its distance from the camera.

Because game design is an iterative process, parameters were made to be tweaked as easily as possible and they work together with procedurally generated content. This means that almost every attribute in the game is a dynamic value.

## 5.3 First Impressions

The first version of the game was tested with a few people different than the focus audience. People of different age usually understand controls similarly, but difficulty is a different matter. Absolute difficulty and perceived difficulty must be iterated with the focus audience for this game, especially because mathematics is an integral part of the game mechanics.

The best approach to having the game tested was to pick out people who had never heard of the game. The game was handed over to the testers without introductions because it is important not to tell everything about the game to the testers upfront. Helping too much affects the feedback you are going to get adversely. When starting the testing, the first few seconds are the most important, because you can see how the player intuitively interacts or tries to interact with the game.

The effortless, fluid use of the tilt sensor and accelerometer produced an enjoyable and responsive controlling experience. Controlling the avatar horizontally by twisting the wrist of your hand clockwise and counterclockwise felt natural, but many of the testers were trying to give the avatar more speed by tilting the smart phone away from to player. The testers also reported not being able to control the avatar in its assumed entirety. This created a feature request on the possibility to control the jumping height of the avatar. This led to the iteration process of 3 different control schemes.

## 5.4 Controls

Controls are integral for a fluid gameplay experience. Any lag or unresponsiveness will alienate a potential player even before the player has understood the goal of the game. 3 different control schemes were iterated to find the best possible player experience. The only basic control that was not changed, was the horizontal control of the avatar by twisting your wrist.

### 5.4.1 Automated jump height

This was the simplest of all control schemes, but it led to dissatisfaction of the player. The player did not feel like he/she was in enough control of the avatar. When the player was about to answer the multiplication problem by bouncing the ball towards the right goal, the player felt frustrated for not being able to answer to the problem as soon as they knew to answer. This is because the avatar was forced to bounce around 4 times before it reached a high enough jump to reach one of the goals. This also led to the game being slower and having a smaller sense of urge, which was not one of the criteria this game set out to achieve.

### 5.4.2 Jetpack and tap to jump higher

To aid the problem of answering not being possible as soon as the player knew the right answer to the multiplication problem, a “Tap to jump higher” –scheme was introduced. With this control scheme, the player could tap on the screen to make the avatars next jump be high enough to reach the either of the goals. Also by holding the finger on the screen the player could give the avatar a jetpack-like force upwards. In the end, this control scheme deemed unnecessary and took away the fun in bouncing.

### 5.4.3 Tilt the phone to jump higher

This control scheme reduced the need to push any buttons and relied only on tilt controls and the accelerometer. This control scheme fits the game the best. The only problem is how to communicate the control scheme to the player. A sophisticated approach would be to show the tutorial to the player, if in a certain amount of time, the player cannot progress in the game.

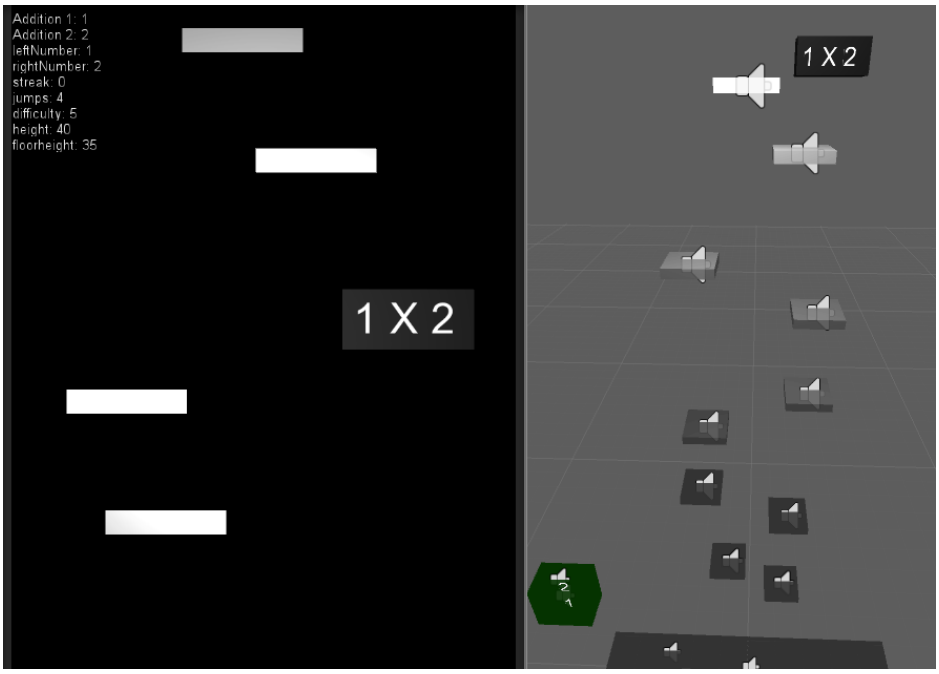
## 5.5 Acceleration versus tilting

During play, some of the testers were trying to constantly give the avatar more jumping height by creating a throwing accelerating motion with the phone. The

problem is that this does not create more jumping speed. Only the rotational position of the smart phone affects the jumping height. This feature was left to be implemented after the release if necessary.

## 5.6 Controls

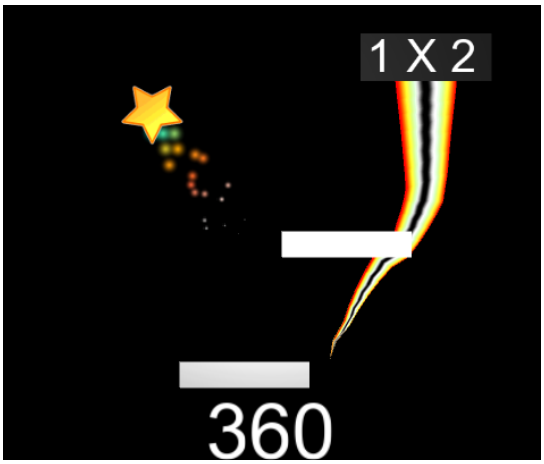
The early testers reported the game as being too repetitive. The continuous problem solving left the players feel exhausted and they lost interest in the game. It was clear that they had come out of the flow channel and the game was in need of pacing. Thus, some level design between problem solving, was introduced. Basically the set of controls and game mechanics enabled a platformer-like game that was played vertically, not horizontally. This translated to fun gameplay and a goal of trying to bounce the avatar higher and ever-higher.




Picture 5. Game- and Editor-view of the platforms created between problemsolving

## 5.7 Score

To further motivate the player, a basic score game mechanic was implemented in the form of collectable stars and the players reach upward. The player gets a better score by playing the game higher and higher. Also each star gives a onetime bonus score of 200 points when touched upon. There are always 3 stars per platform jumping intersection. A right answer scores the player 2000 points.




Picture 6. Stars and scorekeeping

The aforementioned jetpack controlling scheme was tied into the stars by making the stars act as fuel for the player's jetpack. A fuel indicator was implemented to show how much jetpack power the player had. Testers felt this feature was illogical and not really necessary, so it was removed.

## 5.8 Adaptive difficulty

To keep the player in the desired flow channel, an adaptive difficulty mechanic was created. In addition to the score, a streak of right answers was indicated by a number on the screen. Every time the player got five right answers in a row, the difficulty was raised for the next set of math problems. If the player would answer wrong, the difficulty was lowered.

## 5.9 Generating math problems

The basic principle of how the math problems are generated is very simple. A basic algorithm generates two random numbers that are multiplied and the answer is stored for later use. A minimum and a maximum number are given to the algorithm according to the current difficulty level. In addition to the right answer, a fake answer is also generated. The fake answer needed to be a few numbers off of the right answer, so the player cannot guess the right answer too easily. Also, when the two generated numbers are both even numbers, the right answer is always an even number resulting in a problem if the fake answer is an uneven number. It is then too easy for the player to guess the right answer.

The difficulty rises indefinitely if the player always answers correctly. Some kind of endgame needed to be developed. The options were to make the game a race against time or include lives, which would decrease if the player answers wrongly. The game mechanics did not complement a race against time very well, so 3 lives were given to the player as batteries for the main character. Every time the player answers wrong, one battery is depleted.

## 5.10 Feature lock

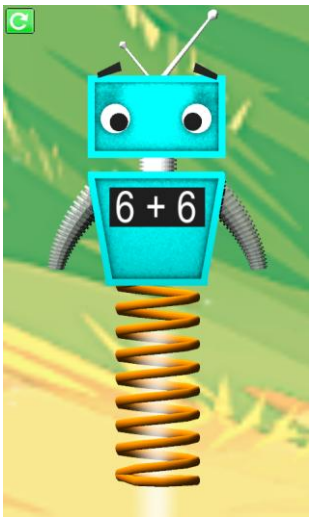
For the purpose of the Minimum Viable Product, the game was feature locked. No new game mechanics were to be added without drastic feedback of from the testers. The game was now playable, it had a start, goal and an end.

# 6 AESTHETICS

A successful game is a harmony of multidisciplinary components. Graphics, animation, story and sounds complement the gameplay mechanics that draw out important events and set the mood.

## 6.1 Avatar

The avatar is an old household robot that is thrown away to a dump, because it could not do basic math operations anymore. In the dump, the robot slowly reactivates and determines to fix itself by learning the math operations again.



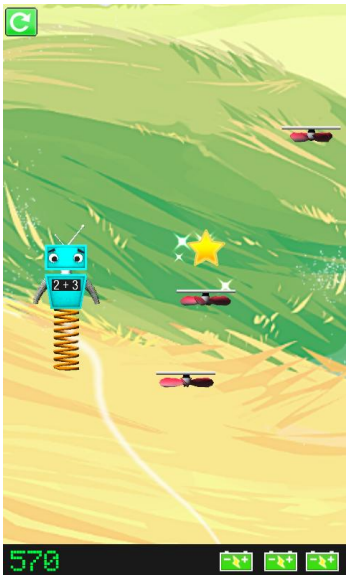

Picture 7. Avatar in flight

The avatar looks very kind and a bit of helpless, to boost the sense of the player helping the avatar. The multiplication problem is presented in the robot's torso, in a kind of a TV. When a new problem is generated, the camera zooms to the problem and quickly zooms out when it is time to bounce around again. When the player answers correctly, the avatar raises its eyebrows, delighted.

## 6.2 Audiovisual components

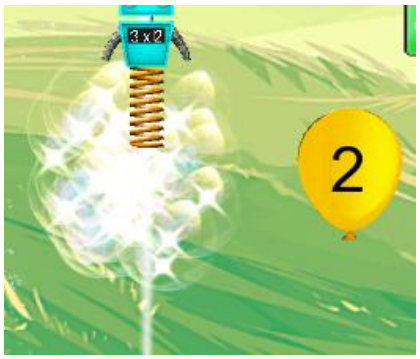
Graphics are a mix of 3D and 2D objects. The avatar was made in 3D to give it a little more life and a bit of texturing creates shading. The avatar also rotates and the jumping spring stretches accordingly to tilting the phone. Platforms stay

in the air by a rotating propeller and the background is a brightly colored grass field with hills.




Picture 8. Gameplay screenshot of the game

The collectible stars are 2D still images with a particle emitter. The background slowly goes down when the player progresses in the game. Score, lives and the menu button are reserved for the corners. A custom pixel-style font was used for all the text in the game. A restart button was added for accessing the main menu.




Picture 9. Right answer

In the above picture, the player has just answered correctly and bubbles appear when the balloon is burst. If the player answers incorrectly, the balloon flies

away with its air emptying. Different sound effects are used in key gameplay events, such as answering, jumping and collecting a star.

# 7 POLISHING AND PUBLISHING

During the development of Math Jump, an opportunity to test the game with a focus group raised from TOP-Keskus. TOP-keskus stands for “Tietokone opetuksessa” and it manages the IT-purchases in schools around Turku. TOP-Keskus owns Acer Iconia Android-tablets, which are loaned to kindergartens and schools for educational use. Kids use the tablet devices to play educational games and use productive apps.

## 7.1 Focus group

Suotorpankujan päivähoitoyksikkö notified us that they would be interested in testing the game. [36] They had a group of six-year old kindergarteners, 6 boys and 1 girl. The test case was scheduled in the morning and it lasted one hour. The children were split into two groups.

## 7.2 Test setting

The game was modified to generate only addition problems, because multiplication problems would have been too hard. Every child got their own Android-tablet to test the game. For each child, the game was launched by the instructor and the controls of the game were left for the player to figure out. The children could play the game for as long as they wanted.

## 7.3 Testing

Most of the kids understood the control scheme by their own. Only one child required a helping hand and some instructions for controlling the game. Understanding the controls took a lot of time, but no-one gave up or lost interest in the game before they could understand the controls. About half of the children understood the objective of the game almost instantly, the others followed once they were skilled enough with the controls.

The generated addition problems were restricted to have a maximum right answer of 20. The children had to think hard, as this was pretty challenging, but

they did not frustrate at any time, aside from one child, who thought the problems were too easy and lost interest in the game after about 10 minutes. The rest of the children played the game for almost 30 minutes and they were asked to stop playing, as they would have willingly played it more.

### 7.4 Negative feedback and other notices

Based on the test case, a few game design faults and bugs were identified.

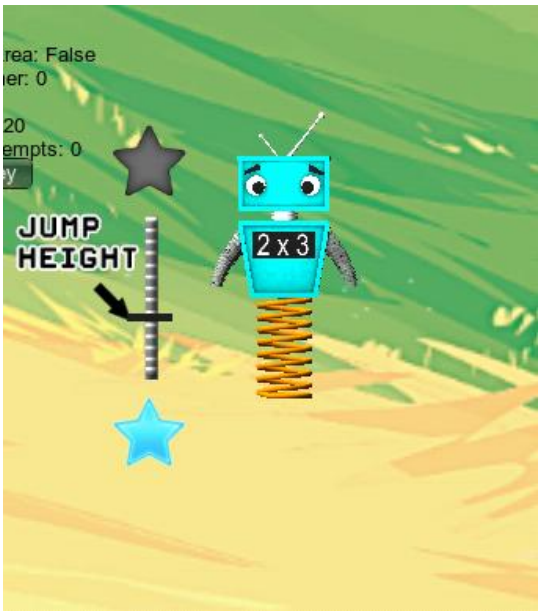
- When the player advanced through the platforms and onto the math problem, the players did not have enough time to slow down the jumping, which resulted in answering the math problem accidentally, whether the answer was right or wrong. It took too long for the players to understand to slow down the jumping.
- Just after the math problem, the platform that follows is too hard to reach, because it needs the maximum jumping height to reach it.
- There was something wrong with the game logic that made wrong answers sometimes go unnoticed.
- If the game was played too long, it automatically crashed at some point, indicating a memory problem.
- Points and lives were indifferent to six-year old players.
- The animation and sound feedback the players gets for answering the math problem was not clear enough.

### 7.5 Positive feedback

The controls were fun to play with and the graphics were good and pretty consistent. Sound effects gave good feedback and support for the game core mechanics. The children had fun playing the game, often laughing and cheering for getting the right answer. The teacher felt impressed for the game and had high hopes for developing the game further. Although the game had problems, it showed initial promise.

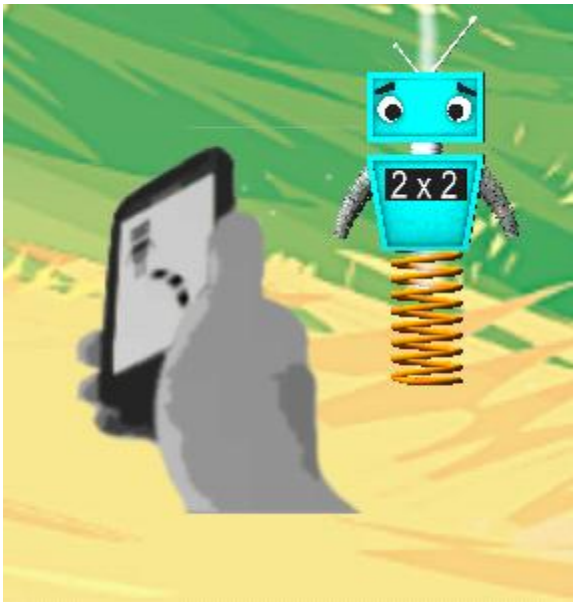
## 7.6 Polishing

First-time players do not know how to play the game, so a brief tutorial was added to teach the player the controls. Many of the players did not understand fast enough the connection with tilting the phone and the movement of the avatar. The tutorial is split into two parts.




Picture 10. The player has hit the minimum jumping height on the scale

First the player needs to learn that tilting the phone up and down affects the height of the jump. A scale with an indicator presents how the phone is tilted. The player is required to tilt the phone and hit the minimum and the maximum jumping height on the scale to proceed in the game. A blue star indicates a hit and once both of the stars are blue, the player is able to proceed.




Picture 11. Horizontal movement tutorial

The tutorial for horizontal movement is an animation of a hand tilting a phone. The tutorial is only triggered, if the player does not understand to tilt the phone left and right to control the avatar. Once the player has travelled higher in the game, all tutorials are disabled.

The simplest form of a multiplayer was also implemented, a high score. Different players can now compare their scores to see who is the best player. The high score is displayed in a simple menu outside the gameplay scene. The game still lacked a clear ending and it needed an indefinite stop. The exercises were made to become infinitely harder and harder. Also, when the player is about to answer to the multiplication problem, the platform under the player was designed to rise slowly, so that the player could not ponder the right answer forever.

## 7.6 Publishing

The Appstore and the Google Play Store both require a developer fee for publishing applications or games. Appstore's yearly iOS developer fee was 99$ and Play Store's Google Play Developer licence 25$ at the time of publishing. Appstore requires the developer to be a legal entity, such as a company, before

an app can be published there. Apple's process requires every company to send a cover letter by fax signed by its CEO, proving that the company is real. This letter must be accompanied by a certificate from the National Board of Patents and Registration of Finland. Google Play Store's process includes the aforementioned only after you put up paid applications into the store. Both stores offer publishing free or paid applications for free, provided by the 30% revenue cut from revenue on either store.

Math Jump was prepared for publishing to the Appstore and Google Play Store with a few things in mind. The name needed to be something that was not in use already in the Appstore or Google Play Store. The name also needed the word 'math' so users can find it more easily when searching for a math game. The first idea for the name was 'Mathness', derived from the word 'Madness'. Unfortunately, this was in use in the Appstore. In the end the name 'Math Jump' was chosen, because it was free to use and describes the game in two words.

One of the first things a potential downloader will see is the icon. The icon was made to be attractive and polished. The icon also somewhat conveys the idea behind the game.


Picture 12. Icon

After the potential downloader has clicked the icon accompanied by the name of the game a description and screenshots are shown. These screenshots communicate the idea of the game and encourages the user to download the game.

# 8 SUMMARY

Math Jump is now available in the Google Play Store and the Apple Appstore. The game can be found by entering the name ‘Math Jump’ into the search field of either distribution platforms.

Producing a minimum viable product was a big undertaking for a small mobile games company. Luckily the tools used for creating the game were robust and the main focus could be given to the game design. NordicEdu learned a lot about producing games with Unity and the company will use it more extensively in future projects.

Initial testing of the game has showed it promise from kids in the target audience. The game development process could have gained more from testing the game earlier. Especially, the control scheme could have been decided upon earlier. Challenges were also met in coding the physics and the dynamic variables needed for iterative game design. The decision to start monetizing with the game was left for later evaluation.

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