FAMILY QUEST

# 2020

## BRINGING FAMILIES TOGETHER THROUGH AUGMENTED REALITY

Ollie Golub

# 1. Information Page

*Title*
Bringing Families together through Augmented Reality

*Main Research Question*
How can the Family Quest framework be supplemented with a mobile AR application, with optimized performance and user experience, to improve immersion of families playing at home?

*Graduation Company*
Family Quest

*Student*
Ollie Golub
431887@student.saxion.nl
Game Design & Production

*Company supervisor*
Mark Boerrigter
m.j.boerrigter@saxion.nl
Founder
Family Quest

*Saxion supervisor*
Taco van Loon
t.vanloon@saxion.nl
Docent / Coordinator Game Engineering / Design studies

*External Guide*
Bob-Jan ten Cate
info@therebellion@studio.nl
External Guide
THE REBELLION

## 2. Acknowledgements

I would like to thank Mark Boerrigter and Family Quest for bringing me in as part of the team. I am glad I got to work towards furthering their mission for almost a year and a half. Mark's help and understanding during this project were invaluable to my development as a professional and I would be happy to work as part of his team in the future.

I would also like to thank Taco van Loon for his advice and guidance during this project. This graduation period has not been a typical one, and I am thankful to Taco for helping me through the uncertainty. Similarly, I am thankful to Bob-Jan ten Cate for providing me with helpful recommendations.

Additionally, I would like to thank my teammate, Melissa Wildschut for helping with my creative progress and providing an enjoyable work environment. As well as, Christian Rietbergen for his help during the development. His expertise, recommendations, and good humor were invaluable in the creation and improvement of the prototype.

## 3. Abstract

During my graduation, I worked with Family Quest to further their mission of getting parents and children to play together in this digital age. Family Quest is always looking for a way to improve their framework with interactive stories supplemented with real-world missions. For this graduation, they have tasked me with evaluating mobile AR as a way to enhance this framework.

Throughout this project, I have researched different toolsets necessary for mobile AR development, ways to increase immersion, and improve user experience, as well as how to add value to the Family Quest framework. As a result of this research, I designed and developed a mobile app with two AR missions. This app has been tested with the target audience and shows promising results for the potential of mobile AR. Additionally, I have created a guide for further AR implementation that can be used by Family Quest in the future.

## Table of Contents

## 4. Glossary

*Augmented reality (AR)*

AR is an interactive experience of a real-world enhanced by the use of technology, overlaying it with computer-generated content. It is commonly used in video games, television and personal navigation (Christensson, 2016).

*Install base*

Install base refers to the number of units of a certain product, usually software or application, that are currently in use. (Farlex, Inc, 2015)

*Software development kit (SDK)*

SDK is a collection of software tools and programs that can be used to build applications for specific platforms. SDKs are mostly used in mobile development (Valdellon, 2019).

*Usability testing*

Usability testing is a type of product evaluation performed by testing it with representative users. The testing often involves participants trying to complete certain tasks, while observers take notes (Moran, 2019).

## 5. Introduction

In the modern day and age, both parents and children spend a lot of their free time on electronic devices. With all the advantages technology gives us it is only natural that there is a downside. Excessive use of technology and the internet has a negative impact on children's mental health (OECD, 2018). It also fosters a family divide according to Taylor (2013), hurting family communications and making children feel less supported by their parents. It prevents real connection and play, which is crucial for a better everyday life at home, as it allows both children and parents to connect with others, learn, express their creativity and unwind from day-to-day pressure (IKEA, 2017).

Family Quest is a Dutch start-up company whose goal is to get families to play together again. However, they believe that taking the devices away from parents and children is not an option. Instead, they want to use modern technologies to create a framework that balances real-world activities with screen play. Such balance is believed to have a positive effect on children (IKEA, 2017).

According to Cubicle Ninjas (2019), mobile AR has reached the new heights of popularity, therefore Family Quest wants to implement it as part of the framework. Mobile AR is convenient, portable, does not require an expensive headset, and can seamlessly run on most modern smartphones. With the release of new SDKs, the development process of AR applications became much easier. From mobile games to home retail, AR is finding its uses in all types of industries, and there is still a lot of potential for practical, creative, and social AR applications. However, working with AR and especially mobile AR provides a set of unique challenges. It is not enough to simply add AR as a gimmick, the design of the experience needs to support it in a meaningful way. Additionally, even with modern smartphones, optimization needs to be an important consideration when developing for mobile. It is important to provide the users with a seamless, engaging, and aesthetically pleasing experience.

## 6. Assignment

### 6.1 Company Outline

Family Quest is a Dutch startup company, founded in 2016 by Mark Boerrigter. He and several volunteers begun working on an application that aims to help parents and children overcome the divide and start playing again. Their idea was to create a platform for interactive stories that would involve several real-world games and activities, that need to be completed to progress further in the story. Some of those activities can be done by a child independently, and some require help from the parents, encouraging them to spend time together. Currently, Family Quest is an early-stage startup focusing on developing and releasing a physical version of their stories, collectively referred to as "Project Cereal", as well as the digital framework.

### 6.2 Graduation Assignment

Family Quest is always searching for ways to enhance their formula of storytelling and bringing families closer together. Currently, they are looking into using Augmented Reality technology to enhance their product. They found web AR, that they tried to use in the past, very limiting, and are considering using a different platform for the development. The first attempts at creating AR experiences using the Unity engine and ARCore showed promising results. They are looking to further investigate the possibilities of AR implementation to increase the player's immersion.

### 6.3 Preliminary problem definition

Family Quest wants its formula of interactive stories with real-world missions to gain attention. They are planning to implement AR as part of their first to be released digital story, to enhance the players' immersion and stand out from the competitors. Due to the limitation of web AR, they are looking for an alternative means of implementation within the framework. Currently, Family Quest is investigating mobile AR and is requiring research into necessary tools and implementation guidelines. To conduct this research, they need a functional prototype of several AR missions, as well as documentation to support future development.

## 7. Theory

Based on the preliminary problem definition, theoretical research has been broken down into five sections: mobile AR, User Experience, Family Quest, immersion, and the design process.

### 7.1 Mobile Augmented Reality

### 7.1.1 What is the current state of mobile AR?

The popularity of mobile Augmented Reality has been rising in recent years. With the advancement of modern smartphones, mobile AR can be easily accessible, convenient, and comfortable, unlike the expensive and bulky AR headsets (Cubicle Ninjas, 2019). In 2018 it delivered the revenue of $3 billion and reached an install base of over 850 million globally, according to Digi-Capital (2019).

This rise in popularity can be attributed to the new developer tools, such as Apple's ARKit which was released in June of 2017 and Google's ARCore following in March 2018 (Seal, 2020). With those new SDKs, developers can more easily design and create apps for both iOS and Android, distributing them to a wide-open market.

Mobile AR is finding its application in many different fields, from games like famous Pokémon Go to more practical apps, such as IKEA Place – a home furnishing app that lets the users preview products using AR (Cubicle Ninjas, 2019). Many big brands and companies, such as the New York Times, Converse, MTV, and Amazon are beginning to include mobile AR in their marketing and commercial applications.

A number of new features have been developed in the past years, according to Cubicle Ninjas (2020), such as shared AR experiences - allowing multiple people to join on AR experience, human occlusion, which lets virtual objects hide behind people and contextual understanding that makes the virtual objects truly interact with the real world. All those new features open new possibilities for creative AR applications.

### 7.1.2 What is the future of mobile AR?

The future of mobile AR seems to be even brighter, according to Digi-Capital (2019). They forecast that mobile AR could top $30 billion revenue and an install base of two and a half billion by 2023, making it a rapidly growing market with huge potential.

Mobile AR is predicted to continue becoming prominent in different industries, such as online shopping, healthcare, and manufacturing (Seal, 2020). More importantly for Family Quest, its potential in education and entertainment is undeniable. AR allows people to learn through visual and tactile experience, as well as interactive games and activities.

In the meantime, technology and tools will continue to advance, making "AR development—from asset creation to real-world interaction—better and more viable" (Oragui, 2019).

### 7.1.3 What tools are used to develop AR apps?

The development of an AR app from scratch is a challenging task, which can be greatly accelerated with a suitable Software Development Kit (SDK). There is a great number of SDKs available, varying in costs, from free and open-source ones to requiring yearly commercial license subscriptions, as well as supported platforms, features, and limitations.

### 7.1.4 What types of AR apps are there?

AR apps can be broadly divided into marker-based apps and location-based apps.

- **Marker-based apps** rely on identifying and tracking predefined markers, like QR codes and images, to overlay them with digital content. Several more advanced SDKs can also support the recognition and tracking of 3D objects, such as faces and products.

- **Location-based apps** do not require markers, they use GPS, camera, and various internal sensors to show the AR overlays over the physical world.

### 7.1.5 Challenges of mobile AR implementation?

Lack of design & development standards – AR technology is new and therefore there are little agreed on universal technical standards, which makes development slower and more complicated.

Hardware limitations – most SDKs, especially the ones like ARKit and ARCore are only supported by the latest smartphones, which limits the target market.

Possibility of physical harm – the virtual overlay can distract the users from the real world, making them prone to accidents and injury. It is important to take this into consideration when designing the app.

Lack of awareness – according to Buckle (2019) only 65% of consumers are aware of AR. Overcoming the lack of information and knowledge can be a challenge when trying to develop and promote the app.

Meaningful implementation - one of the main challenges of AR design and development is to create a meaningful experience for the user, as it is not enough to simply add AR as a gimmick.

## 7.2 User Experience

### 7.2.1 Definition

The term User Experience (UX) was created by Don Norman in the late 1990s, who said that UX "encompasses all aspects of the end-user's interaction with the company, its services, and its products" (Lamprecht, 2019).

### 7.2.2 User Experience Honeycomb

In 2004 Peter Morville developed the UX Honeycomb to illustrate different facets of user experience. In the years since it became a popular and well-known visualization tool. Katerina Karagianni (2018) later optimized the model to further demonstrate the relationships between the qualities (Figure 1).

The UX Honeycomb contains seven facets:

- **Useful** – the product needs to fulfill a need of the target user.
- **Usable** – the product needs to be simple and easy to use.
- **Desirable** – the product's design needs to be visually appealing.
- **Findable** – it should be easy to navigate and find information.
- **Accessible** – the design needs to accommodate users with disabilities.
- **Credible** – the product and information need to be trustworthy.
- **Valuable** – it should further the company's goal and improve customer satisfaction.



The facets are grouped by how the users interact with the product:

- **Think** – what do users think?
- **Feel** – how do they feel about it?
- **Use** – what is their experience with using it?

*Figure 1*. The Optimized UX Honeycomb (Karagianni, 2018)

### 7.2.3 How to improve UX in a mobile AR app?

According to the Google's Augmented Reality Design Guidelines (Google, n.d.), Apple's Human Interface Guidelines for Augmented Reality (Apple, n.d.) and Anna Chakravorty (2018) there are several recommendations to improving user experience in an AR app. They mostly refer to keeping the app usable, findable, and accessible. A more detailed summary of the UX recommendations can be seen in Appendix II.

Those recommendations can be broadly divided into those categories:

- **Getting started** – the user should be guided through the setup process to make sure they do not get frustrated or confused.
- **Comfort and safety** - to take into account the user's physical scenario – are they using the device in public or in private, do they need to use their full body to move or can they use it while sitting or wearing a wearable.
- **Information and control** - let people use the entire display by devoting as much of it as possible to showing the real world and the virtual content.
- **Object placement and interaction** – pick the placement method best suited to the experience and allow the users to interact with virtual objects.
- **Movement and discovery** – encourage users to move and interact with the environment.

### 7.3 Family Quest

In his User Experience Honeycomb, Peter Morville (2004) describes a valuable product as the one that delivers value to the sponsors. It can either be profit or advancing the mission, as well as customer satisfaction. Family Quest is a value-driven business that aims to get parents and children to play together in this digital age. They are aiming to create a framework that will feature multiple interactive stories with real-world missions for different ages and interests. For Family Quest, a valuable product would be the one that fits within the framework and helps achieve said goal and satisfy customers.

### 7.3.1 Family Quest Framework

Mauricio (2018) in "Family Quest: Getting kids to play in a digital world" outlined the Family Quest framework as offering "family adventures, consisting of short missions that make up a larger storyline" with those missions being "easy to set up and diverse in their content" (p. 32). He discovered that the value definition for children was "fun, exciting and creative games that span multiple interests" (p. 27) and for parents - "facilitating family-wide games" (p. 27).

### 7.3.2 Target Audience

Marketing analysis conducted by Heuvel and te Riele (2019) defined Family Quest's target audience as creative families that like to spend time with each other. Specifically, parents aged 34 to 43 with children from 4 to 12 years old. The parents have high education and are economically independent, living mostly in North and South Holland.  The children themselves are the secondary target group. At the age of 4 to 12 they go through different stages of social development, learn how to emphasize, build relationships, and develop their own values. Family Quest aims to create a variety of stories that will be suitable for children of different ages.

### 7.3.3 Family Quest and AR

Family Quest has already conducted some research into AR implementation. During the SSS I analyzed existing AR apps and guidelines for AR design. There were several brainstorming and discussion sessions during which the basic ideas for the AR missions were created. The results of those can be seen in Appendix XI.

## 7.4 Immersion

### 7.4.1 Definition

Nikolayi Engelmann (2018) in his book "Virtual Reality Gaming" noted that:

> Immersion (the technical term for immersing oneself in an artificial world) describes the effect caused by a situation, environment, or graphic representation which makes the user's consciousness recede into the background so that the virtual environment is perceived as reality.

Staffan Björk and Jussi Holopainen (2004) describe four different categories of immersion:

- **Sensory-motoric immersion** – occurs when you perform actions and get feedback from all five senses – sight, sound, touch, smell, and taste.
- **Spatial immersion** – happens when the player perceives the simulated world as convincing.
- **Cognitive immersion** – this category is associated with focusing on a mental challenge.
- **Emotional immersion** – occurs when the users become emotionally invested in the story.

### 7.4.2 Presence

There can be a further distinction made between "immersion" and "presence" when talking about virtual experiences.

Slater (2003) defines immersion as a measurable level of fidelity, the ability of a virtual world to appear to all senses as the real one. At the same time presence is a subjective feeling of "being there" and engaging with the environment as if it was real. Presence is affected by immersion, even though a different user may have a different sense of presence when experiencing the same virtual situation. It is easier to measure and control immersion, as it is more subjective.

### 7.4.3 How to improve immersion and presence in an AR app?

*Interactivity*

To engage the player more fully, it is important to add elements of interactivity. Allow the player to choose their own paths, move through, or interact with the environment. Meaningful interaction that allows the player to modify their environment in a way that makes sense is key to keeping the users engaged. Jonathan Strickland (n.d.) notes that the users would feel more immersed in a virtual environment when provided with interesting interactions, even if the environment itself is not realistic.

*Gamification*

Gamification is defined by Brian Bruke (2014) as "the use of game mechanics and experience design to digitally engage and motivate people to achieve their goals". Gamification relies on four elements that each game has: a goal, a set of rules, a feedback system, and voluntary participation (Eşanu, 2018).

There are many ways to implement gamification. Often it is done by adding points, badges, or collectibles to signify achievement and progress. A more complex approach can involve a leveling system, a sense of community and competition or a personalized avatar.



*Figure 2*. Three screenshots of the mobile app Duolingo. (Eşanu, 2018)

An example of gamification implemented by the educational mobile app Duolingo can be seen in figure 2. As long as you presents the user with "clear, immediate actionable goals and show [them] direct and immediate feedback that [they] achieved them" (Burke, 2014) you can make any work satisfying.

### Avoid the Uncanny Valley

The "uncanny valley" is a term first used by the Japanese roboticist Masahiro Mori in 1970 to describe how the more human-like robots become the more appealing they seem, but only to a certain point (Lay, 2015). Uncanny valley refers to specifically that dip in the relationship between the human-likeness and emotional appeal as seen in Figure 3. It can be more broadly used to describe the existing "gap in the acceptance of artificial content" (Mobfish, 2019).



*Figure 3*. The Uncanny Valley in the Affinity chart based on the percentage of robot likeness to humans (Lay, 2015)

When designing immersive content, it is important to stay out of the uncanny valley by balancing realism with the appeal. However, it is also important to remember that different users would have different reactions to similar content. What for one user can seem realistic, for the other can appear unsettling.

### Performance & Believability

Ensuring optimal performance and believability is important to not only increase immersion but also to avoid motion sickness and nausea. If what the user's brain is telling them doesn't match up with what they are seeing, they won't enjoy the experience (Burrows, 2019). It is not necessary to aim for photo-realistic visuals, but rather focus on creating a believable environment that matches the user's perception of the real world. To achieve that, it is important to strife for high frame rate, so that the virtual content moves with the same speed as the camera. Objects and characters need to have a realistic scale to appear believable. The realism of lighting and shading can also affect it.

### Spatial Sound

When designing an immersive experience, one should also consider how sounds effects will match the position of virtual objects. For diegetic sounds, which are the sounds that have a source on-screen, it is important to use spatial audio. According to Burrows (2019) "spatial audio uses a dimensional approach to audio – creating a full-sphere soundscape which mimics real world sound". If the AR experience involves sound effects, including spatial audio can greatly improve the user's spatial immersion.

### Emotional Context

It is important to engage the users in the story and characters, making them invested in their outcome and development. This creates emotional immersion, which can greatly improve the sense of presence and enjoyment.
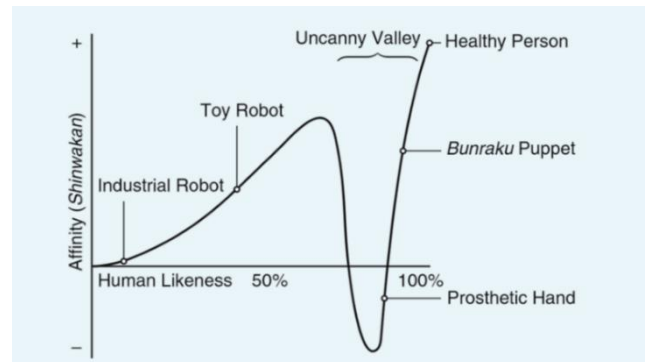
## 7.5 Design Process

### 7.5.1 What design method will be used?

User-centered design (USD) is "an iterative design process in which designers focus on the users and their needs in each phase of the design process" according to Interaction Design Foundation (n.d.). USD involves understanding the user base, what they need, and how they will use the product, before designing and developing said product in iterations, evaluating it with usability testing.

According to (Gladkiy, 2018), USD process includes six phases:

- Specifying the use context and users' needs
- Specifying business requirements
- Building design solutions from rough concept to finished design
- Evaluating designs with usability testing
- Implementation — developing and delivering the product
- Deployment — the final product is evaluated, as consumer needs change.

### 7.5.2 Stages

As per the implementation plan, I will not be designing the AR experiences from scratch but basing them on the preliminary designs developed by Family Quest in the past. However, I will be designing the AR app and its interface.

Following steps would be followed in the design process:

- Wireframing
- Mock-up
- Prototype

*Wireframing*

A wireframe is a "low-fidelity design layout" (Fanguy, 2019) which is used to place the basic content and functionality, taking into account user needs and user journeys.  Wireframing is an important step in designing an app, which helps the developer plan the layout and see user interaction without the distraction of aesthetics and content.

*Mock-up*

The next stage in the design process is a high-fidelity mockup. This stage involves adding visual design on top of the wireframe to communicate what the final product would look like (InVisionApp Inc., n.d.).

*Prototype*

The last stage of the design process is prototyping. The goal of the prototype is to test functionality, user experience, gameplay, and visuals to see if the idea is worth pursuing (Stefyn, 2019). The prototype is developed in iterations, starting with placeholder assets to make sure the concept can be tested and improved as fast as possible.

## 8. Problem Definition

Family Quest wants to help families play again in this digital age. They want to enhance their framework of interactive stories with real-world missions, by supplementing it with mobile AR. Their goal is to create a mobile app with several AR missions, which would increase the immersion of the player. To do so, they need to know what tools to use and how to optimize user experience, while keeping the app meaningful to the story and adding value to the framework.

## 9. Research Questions

### 9.1 Main question

How can the Family Quest framework be supplemented with a mobile AR application, adding value to the framework, optimizing user experience, and improving the immersion of families?

### 9.2 Sub-Questions

1. What existing tools can be used to develop a mobile AR app?
2. How to implement AR in a way that adds value to the Family Quest framework?
3. How to improve user experience in a mobile AR app?
4. How to implement AR in a way that improves immersion?

# 10. Methodology

For the purposes of this project, the focus will be on qualitative rather than quantitative research. It is more appropriate in the case of Family Quest, which wants to know how the target audience engages with the potential addition to their product and what their opinion on it is. As the target audience is specific, purposive samples will be selected to participate. Nevertheless, a more qualitative approach will also be used when more precise and objective data needs to be gathered. For example, in the User Experience research, which was used to discover what percentage of the target audience was aware of AR.

Due to the limitations imposed by social distancing, some testing methods specific for qualitative research, such as face to face interviews and observations, were inaccessible. Therefore, the methods that could be easily and effectively be implemented over distance were selected.

Additionally, as Arthur's Quest storyline was still in development, it was impossible to test how the AR app fits within it.

## 10.1 Value Requirements

The AR app must add value to the Family Quest framework, helping advance its mission of bringing families together. To achieve that, theoretical research into the definition of "value", as well as the Family Quest framework and its target audience was conducted. The research was based on a dissertation by Mauricio (2018), one of the founders of Family Quest and a marketing analysis written by inters Heuvel and te Riele (2019).

Based on this research, a set of design guidelines, named "value requirements" was created. They were developed during a brainstorming session with a client and other interns. The final version of the value requirements was approved by the client, making sure that they reflect the needs of the business.

## 10.2 User Experience Research

The objective of the initial UX research was formulated as "to identify the target users' awareness of Augmented Reality". This information would be used in the design process to guide the users through the set-up of the AR experiences, taking into account their knowledge level. Additionally, the participants were asked if they would be willing to participate in usability testing later. The UX Research plan was created to outline the goals, research questions, methodology, participant descriptions, and hypothesis (Appendix III).

The participants were found through Mark Boerrigter and Taco van Loon, as the writer of this report is an international student and does not know any Dutch families. This can affect the results due to familiarity with Family Quest or being connected to the game development study. Parents familiar with the Family Quest concept may have heard about AR from Boerrigter and parents connected to the study can have this information as part of their professional interest. Therefore, I expect a higher rate of familiarity with AR then an average Dutch parent may have.

## 10.3 App Analysis

To design an app that is both easy to use and aesthetically pleasing to the target audience, the research into the existing apps was conducted. The analysis revolved around their UI design – color scheme, style, icons, and layout.

The results of this analysis were combined to create a moodboard and a stylesheet. The mock-up of the app, and eventually the prototype, were based on those findings.

## 10.4 Tool Analysis

To create a mobile AR app an SDK needs to be used. Eight different SDKs were analyzed based on the supported platforms, a range of features and limitations, and cost. The necessary information was found on the SDK's websites as well as in independent sources to ensure minimal biasness. The findings were weighted against the client's requirements.

## 10.5 Prototype

Developing a prototype was essential in answering the research question. The development process allowed for testing of the SDK selected after the tool analysis and the iterations of the prototype were used in usability testing. The final iteration can be released alongside Arthur's Quest storyline, while the findings from the development will be used by Family Quest to make decisions regarding the further AR implementation.

The user-centered design method was used, and the steps outlined in the theory section were followed. The wireframe was created in Adobe XD and mock-up in Adobe Photoshop. The missions were based on the designs created previously by Family Quest inters, which were outline by me in the design document seen in Appendix IV.

The prototype was developed in the Unity Engine version 2019.3.7f1 using C# and an AR Foundation SDK version 3.0.1. Online tutorials, such as AR Portal Tutorial with Unity by Guidev (2018) and Unity3d AR Foundation Tutorials by Punni (2019) were used during the development process.

## 10.6 Usability Testing

Usability testing was used after two completed iterations of the product.

The goals of the testing were to let the target audience provide any further feedback, to learn about their opinions and preferences as well as:

- To identify the main issues negatively affecting user experience
- To see how clear the in-game instructions were
- To understand how difficult and time-consuming the missions were
- To check how well the app performs against the value requirements
- To create a baseline for how enjoyable and immersive the missions were
- To get feedback on visual aspects of the missions and UI

Due to the limitations of social distancing, instead of conducting observation by a moderator, an introduction document was provided to the participants (Appendix V), noting the necessary background information and outlining tasks. To report their experience, the participants then used online surveys.

Five participants were selected from the list of parents that agreed to participate in further testing during the user experience survey. This number was chosen according to Nielsen and Launder (1993), every participant after the first five produces minimal additional value.

It was expected that some participants might be unable to complete the testing in a timely manner, as the demands of work and parenting do not leave them with a lot of free time. It was also possible that some parents would not want to install an unverified app on their phone. Unfortunately, there were no ways to avoid this part of the process at the moment.

## 11. Results

### 11.1 Value Requirements

The value requirements were formulated as follows:

- **Encourages family-wide fun** – the experience needs to be social and include the entire family. For example, the device on which the AR app runs could be easily passed around, allowing multiple people to share the experience.
- **Easy to set-up** – the app needs to be easy for parents to find and set-up. It shouldn't require any technical knowledge or previous familiarity with AR.
- **Short missions** – the playtime for each AR mission should be concise, spanning around 5-15 minutes on average. The focus of Family Quest is to get families to play in the real world, so the app should not take away too much time from it.
- **Customizable** – the missions should be completable in different types of spaces with different amounts of materials. For example, the families playing inside shouldn't need a large open space to place virtual objects, and those who don't have access to a printer should be able to view the markers on the pc screen.
- **Age range** – since the app is aimed at families, the experience needs to be suitable for all ages. It needs to be simple enough for children aged 5-7 years to use.
- **Fit within the storyline** – the AR missions need to make sense within the story context. They should be central to the plot and meaningful.
- **See the unseen** – the AR allows the user to see what would otherwise be impossible, the design of the missions should be focused on providing the users with the experience they wouldn't be able to have otherwise.
- **Reliable** – the AR app should be stable and bug-free to ensure satisfying, immersive experience.
- **Safe** – the app must be safe to use for both parents and children; it shouldn't distract from the surroundings or encourage expansive movements, which can lead to injury.

Those requirements were used during the design and development of the app, to make sure it would add value to the Family Quest framework.

### 11.2 User Experience Research

Twenty-seven people participated in filling in the survey, ten parents, and seventeen children. Among adults, 70% have heard about AR before and have seen apps that use it as seen in Figure 4. After the explanation of AR and provided examples, all parents stated that they have used an AR app before.

None of the children could initially say to have heard about AR. 76% said that they have never heard of it and 24% were not sure. Once they were provided with pictures and examples, 82% were able to say that they have seen an AR app before. All three children that have not seen an AR app were 2-4 years old.

Based on those findings, it appears that the majority of the target audience, both parents and children, have previous experience with mobile AR. However, 30% of the parents and 100% of children tested were not familiar with the definition itself. A full breakdown of the results can be seen in Appendix VI.

As was mentioned in the method section, it is possible that the results were affected by the parents' familiarity with the Family Quest model and/or game development studies.
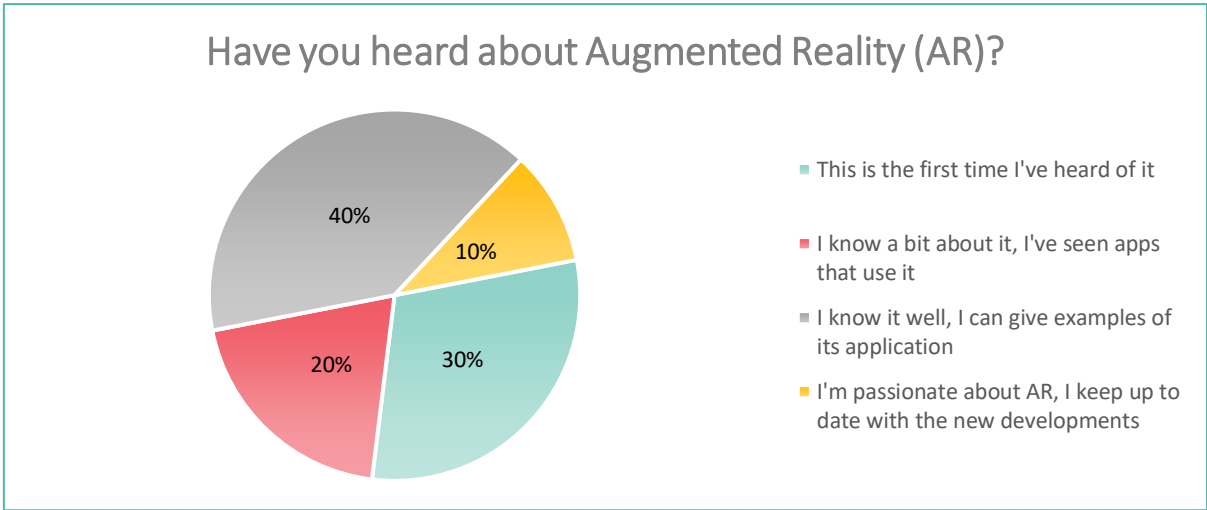
## Have you heard about Augmented Reality (AR)?

- This is the first time I've heard of it
- I know a bit about it, I've seen apps that use it
- I know it well, I can give examples of its application
- I'm passionate about AR, I keep up to date with the new developments

*Figure 4*. A pie chart showing the percentage distribution of the answers to "have you heard about AR?"

Additionally, it was found that designing a survey in a way that allowed for one to four children per parent was not the best option. This resulted in four different sections of results from children that needed to be added up before the outcome of the survey could be clearly seen. They also did not account for multiple parents participating with one child. In the next testing, separate parent and children surveys were created to avoid those issues.

## 11.3 App Analysis

The design of four mobile apps aimed at families and designed to be used by both parents and children were analyzed to see what design choices are made when the target audiences' ages are can vary significantly. Then, as the AR application is meant to mainly appeal and immerse children, with parents supervising and sharing the experience, four apps aimed specifically at children were analyzed. The apps with the themes of exploration, learning about the real world, encouraging curiosity and creativity were picked. To make sure that the analyzed apps were well received, only the apps with a rating above 4.0 were selected.

After eight apps were reviewed, it was clear that apps aimed at families had a significantly different design from the ones aimed at children specifically, as seen in Figure 5. The family apps had a simple flat UI design with white background and blue or green highlights.



*Figure 5*. A selection of screenshots from eight different apps divided into family and children apps.

This could be explained by the fact that most family apps seemed to be designed for organization, chores, and pocket money tracking.

The apps aimed at children had a more colorful UI, matching the cartoony style of illustrations designed to appeal to children. Most of the apps used colored buttons with white outlines, either flat or with cell shading. Several elements of the interface were animated to highlight what should be pressed next or provide instructions. Some elements of interface became part of the game themselves, such as styling tools in Toco Hair Salon 4.

Overall, it is clear that to appeal to children and spark their curiosity it is better to create UI that matches the style of the game itself and is bright, simple, and cartoony. Animated UI can help guide them through the app and provide information. The full analysis can be seen in Appendix VI.

Based on this analysis a stylesheet containing inspiration images and a brief outline of the style was created (Figure 6).
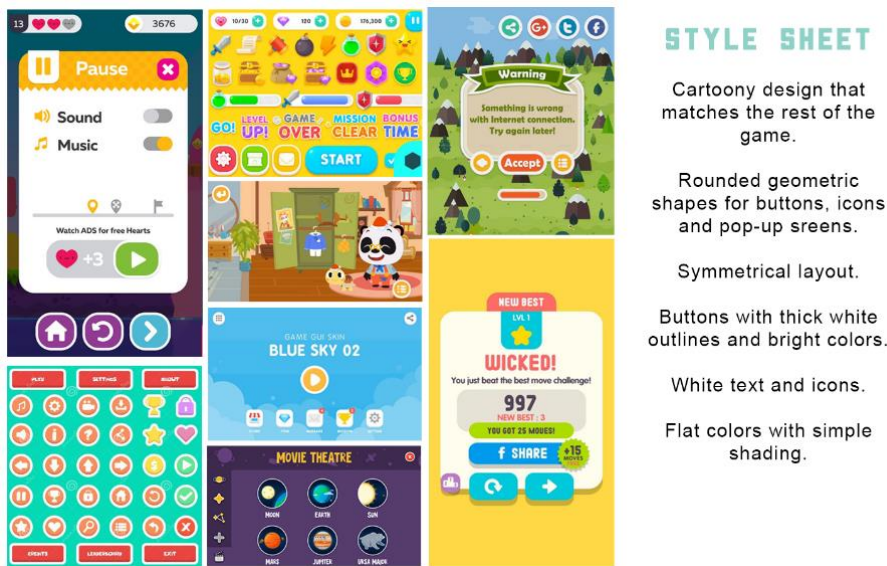


*Figure 6*. A stylesheet with UI examples on the left and a style description on the right.

## 11.4 Tool Analysis

An overview of the tool analysis can be seen in Table 1, while the full analysis can be found in Appendix II.

| SDK | PLATFORM | FEATURES | LIMITATION | COST |
|---|---|---|---|---|
| APPLE ARKIT | iOS | A wide range of features | Only supports iOS devices | Free |
| GOOGLE ARCORE | iOS Android | A wide range of features | Can have issues detecting plane surfaces | Free |
| UNITY AR FOUNDATION | iOS Android Magic Leap HoloLens | Supports features provided by ARKit and ARCore, as well as unique Unity features, provides unified workflow | Limited documentation Some features are not yet implemented | Free |
| VUFORIA | iOS Android UWP | A wide range of features, mostly based on marker AR | Does not have a free version without a watermark | Free version Classic version - $499 one time Cloud - $99 per month Pro version for commercial use |
| ARTOOLKIT | iOS Android Linux Windows Mac OS Smart Glasses | Open-source library with limited features | Only marker AR | Free |
| MAXST | iOS Android Mac OS Windows | A wide range of features | Does not have a free version without a watermark | Free version Pro - Onetime fee - $499 Pro - Subscription - $599 per year Enterprise version |
| WIKITUDE | iOS Android Smart Glasses | A wide range of features, great support | Does not have a free version | Pro version - €2490 per year per app Pro3D - €2990 per year per app Cloud - €4490 per year per app Enterprise version. |
| EASYAR | iOS Android Windows Mac OS UWP | A limited number of features | Performance issues | Free version Professional Edition - $39 per months Enterprise Edition |

*Table 1*. A table showing comparison between eight SDKs based on their costs, features, limitations, and supported platforms.

After the discussions with the client and previous experience with ARCore, Unity AR Foundation was selected due to it being free and specifically designed for development with Unity Engine for both iOS and Android.

## 11.5 Prototype

The prototype was developed in an iterative manner once the preliminary research was completed. Once the design document was created based on the previous designs, the production began.

### 11.5.1 Wireframe

The wireframe was made in Adobe XD (Figure 7). It included all unique main screens and showed the transition between them.

Based on the feedback from the external guide the wireframe was modified to provide a clearer flow. The main menu was adjusted to only show the button for the first mission until it was completed, to make sure the users were clear as to where to start. Additionally, an introduction by one of the story characters was added to further connect the app to the storyline.

### 11.5.2 Mock-up

A mock-up was created after the stylesheet and wireframe were completed. It included the button and panel designs, as well as icon examples. The mock-up was later used to create an in-game UI (Figure 8). The colors of the mock-up were modified to look brighter and the title of the panel was added based on the feedback.

### 11.5.3 Development

The development of the prototype begun by adapting a portal mission created by me during the Smart Solution Semester from an outdated version of ARCore to Unity AR Foundation. Since AR Foundation supports the same range of functions as ARCore, it was expected that the transition would be simple. However, the two toolsets proved different enough to cause issues. The AR Foundation sample kit was extremely helpful in overcoming those difficulties by providing sample scenes and instructions.



*Figure 7*. A screenshot showing several screens in Adobe XD.
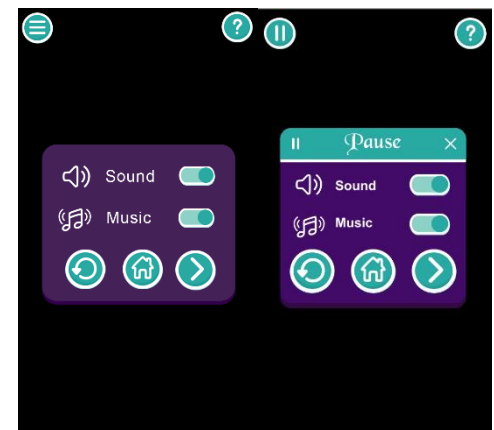


*Figure 8*. A mock-up on the left and a prototype screenshot on the right.

The process of implementation of image tracking for the spell mission was similarly challenging. Even though a clear tutorial by Punni (2019) was followed, it was not functioning as intended. The documentation for AR Foundation was found to be limited and unhelpful. Eventually, I was able to find a Unity forum thread that detailed the same problem. A user Alexis-Dev (2019) discovered that one of the events designed to remove the image was never called on Android while working on iOS. With this information, I was able to work around the problem, however, it was very disappointing, considering that AR Foundation was specifically designed to provide the same functionality for both iOS and Android.

Once those parts of AR implementation were complete, the rest of the development went smoother. After the basic AR functionality was tested, the first iteration of the prototype was assembled for the purpose of usability testing. The layout and UI design were based on the wireframe and mock-up, respectively.
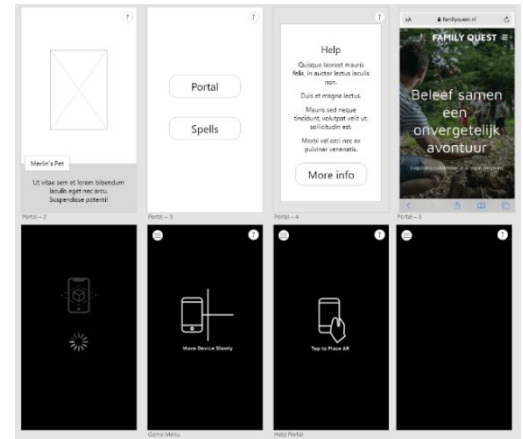
### 11.5.4 First Iteration

The first iteration of the prototype was designed to allow the users to experience the AR functionality and to test their immersion. It included a short introduction by the story character, designed to provide emotional context, a menu with two mission buttons, and a help screen. The portal mission was fully functional, with a few minor bugs relating to the tracking stability. The spell mission only supported one spell and lacked animations and interactive elements. The first iteration of the app can be seen in Appendix X.

### 11.5.5 Second Iteration

The second iteration aimed to further increase the immersion and improve user experience. The prototype was supplemented with the audio effects and a functional pause screen. The spatial sound was attempted, but due its processing requirements was deemed unsuitable for mobile AR, so instead, 3D sounds were added. All three spells were implemented with different visual and sound effects. The bugs and issues discovered during the usability testing were addressed, for example, the colliders for the spell nodes were increased in size to make them easier to press. The second iteration of the app can be seen in Appendix X.

## 11.6 Usability Testing

### 11.6.1 First Usability Test

The first usability testing materials were sent out to five participants, however, only two responded and participated. This can be explained by the factors outline in the methodology section, such as the lack of time and desire to install an untrustworthy app. In total, two parents and four children participated in testing. Full results can be seen in Appendix IX.

Overall, both parents and children highly rated their enjoyment of the missions, with parents giving both missions 4/5, and children rating the portal mission 4.5/5 and the spell cards 4.25/5. Additionally, parents were happy with the visuals of the missions and their suitability for the target audience, while all four children enjoyed creating the spell cloud and 3 out 4 children said that they want to play those types of missions in the future. The immersion was rated 3.5/5 by parents and 3,25/5 for the portal and 4,25/5 for the spell cards by children.

The main feedback involved interactivity. One parent remarked that the portal mission can be improved with the addition of goals, and the other said that the interactivity of the spell cards made them stand out.

The issues brought up by the testers included not entirely clear instructions and the set-up process, one of the parents not finding the missions to be social, and the second one saying that spell cards were difficult to activate for the children.

### 11.6.2 Second Usability Test

During the second usability testing, another problem became clear. Three participants were asked to test, out of those one have not replied and two only had Apple devices in their household which prevented them from testing an Android version of the build. Even though an iOS build could be made, thanks to the Unity AR Foundation multi-platform functionality, the lack of the latest Apple hardware available to the project writer, prevented them from creating a functioning app. After the trial and error, it became clear that even if the app could be made, it could only be distributed for testing with the Apple Development license, which costs $99. Therefore, for now, the second round of testing was postponed.

# 12. Conclusion

## 12.1 What existing tools can be used to develop a mobile AR app?

There is a wide range of available SDKs, varying in costs, supported platforms, key features, and limitations. A full analysis of the top eight SDKs can be found in Appendix II.

Based on this analysis, Unity AR Foundation SDK was selected. It was free, specifically designed for Unity Engine, and allowed to work with AR in a multi-platform way. However, the AR Foundation was found to be still in development and has not fully incorporated all the features of ARKit and ARCore. The documentation and tutorials for this SDK were lacking and troubleshooting took up a lot of development time. Additionally, some of the features, like image tracking, did not work equally well on two platforms.

Based on those findings, it is concluded that while Unity AR Foundation is a good starter choice for mobile development, as soon as it is monetary viable Family Quest is recommended to switch to a more advanced and well-supported SDK, such as Vuforia or MaxST.

## 12.2 How to implement AR in a way that adds value to the Family Quest framework?

To make sure that the addition of AR will add value to Family Quest it must further their mission and provide a satisfying user experience. The mission of Family Quest is to get parents and children to play together in this digital age, so the core design of the AR experience must reflect that.

To help determine how the app can advance Family Quest's mission, a set of value requirements outlined in the results chapter were created. The AR app has to be measured against those criteria during the design and development, to ensure its value. The value requirements could be further tested with the target audience and sorted by priority, to increase their efficiency.

Additionally, to ensure that the customer is satisfied, the user experience should be a top priority during the development.

## 12.3 How to improve user experience in a mobile AR app?

To provide optimal user experience, the user-centric design approach needs to be followed, ensuring multiple usability tests and iterative development. This approach can help to identify the target audience and their needs through UX research, as well as business requirements in the form of value requirements.

More specifically, when developing a mobile AR app, it is helpful to follow the guidelines outlined by big developers such as Google and Apple. They recommend providing a clear set-up guide, outline the ways to ensuring comfort and safety, as well as pleasant interactions and controls. For example, the play sessions should be kept short as to not fatigue the user. The full list of recommendations can be found in Appendix II.

## 12.4 How to implement AR in a way that improves immersion?

There are multiple ways of increasing user immersion based on four different categories of immersion. In a mobile AR app, it is important to engage the user by making the experience interactive and adding gamification elements, through goals, rules, and a feedback system. The addition of emotional context and sounds can also greatly improve the immersion. Additionally, it is important to not strife for total realism as to not fall into the uncanny valley and to make sure that the performance is consistent and reliable.

## 12.5 How can the Family Quest framework be supplemented with a mobile AR application, adding value to the framework, optimizing user experience, and improving the immersion of families?

To successfully supplement the Family Quest framework, the mobile AR application has to further the mission of the company, provide pleasant user experience in all seven facets of the UX Honeycomb and increase user immersion using elements such as gamification and interaction.

To make sure the mobile AR application is adding value to the framework it must adhere to the value requirements of Family Quest. Most importantly, it should encourage family-wide fun, allowing parents and children to share the experience. It should be easy to set-up and customizable, making sure it can be played in most environments, as well as be safe and reliable. Additionally, the app must fit within the storyline to provide an emotional context for the players and make a meaningful connection between the real and virtual worlds. Finally, it must utilize the affordance of AR to allow the users to see the unseen, letting the users experience what would otherwise be impossible.

User-centered design method, iterative development, and usability testing are crucial to creating a design that will provide a great user experience. In a mobile AR application, it more specifically means following design guidelines established by experts, making sure that the user is guided along the way and does not get frustrated or confused. The set-up process needs to be especially clear, as, even though the majority of the target audience has encountered AR in the past, the testing shows that they find this part of the process especially challenging.

Immersion can be achieved through interactive elements, as well as gamification, sounds, and emotional context. The usability testing shows that interactivity is especially crucial to the enjoyment of the experience.

Once those elements are brought together and implemented using an appropriate SDK, the addition of the mobile AR application should greatly benefit Family Quest and improve its framework.

## 13. Discussion and Recommendations

Mobile AR is a new technology that has been rising in popularity and finding its uses across different fields. A variety of brands and companies, from Snapchat to IKEA, had already implemented it as part of the product and the majority of the target audience have experienced AR in one form or another. Mobile AR is proposed to have an even brighter future and a lot of potential in entertainment and education. All of this shows that this technology can greatly benefit Family Quest and help realize its mission.

The development of the prototype even further highlights this. The results of usability tests show that mobile AR is enjoyed by both parents and children while providing higher than average level of immersion. I recommend working on further development and releasing the first story with the AR missions. Those next steps in the app development would involve further improving the user experience and immersion. Based on the usability testing, it is clear that the addition of interactive elements and gamification to both missions, such as hidden collectibles in the portal mission and draggable particles in spell mission can greatly improve them. I recommend researching, implementing, and testing several versions of gamification to see which one will provide the best experience and immersion. Additionally, the set-up instructions need to be clearer, so that neither parents nor children get confused.

However, there are several challenges to the development and release of an AR app that must be taken into account. The main challenges during this project came from two sources – working with a new, still developing technology such as AR and conducting successful usability testing.

The chosen SDK, Unity AR Foundation, while free and promising a wide range of features, had limited documentation and support. This is an issue that tends to happen with newer toolsets, which are still in development and have not been fully tested. It would have been worth the time to investigate the functionality of this SDK further before committing to it. In the future, I would recommend further investigating paid SDKs, such as Vuforia or MaxST. However, it also needs to be considered that mobile AR is a new technology and development issues and uncertainties are unavoidable. It is necessary to dedicate an extra part of the development process for testing and troubleshooting specific AR functionalities.

When it came to usability testing, the UX survey was helpful in providing the information on the target audience's familiarity with AR and for finding potential testers. However, I neglected to ask what mobile operating system target audience uses. This caused issues during the usability testing, as the number of testers was limited by the fact that some families only used Apple products. If I had asked about it in the UX research, I would have had more time to develop an iOS build of the app and could have had data to advise Family Quest on picking the mobile platform. I recommend researching this topic further and based on the results considering investing in the Apple Developer Program, which is required to test and release apps on iOS. Being able to release the app to another target platform will broaden the reach of the app. Additional usability testing sessions conducted with an observer once social distancing is no longer required can provide better insights into the behavior and preferences of the target audience.

Overall, it is clear that mobile AR has a lot of potential for Family Quest. Their next steps should involve more detailed usability testing, final stages in prototype development, and release of the story.

## 14. References

Dr. Panda Limited. (n.d.). *Dr. Panda Learn & Play*. Retrieved from Dr Panda: https://drpanda.com/games/dr-panda-learn-play

Alexis-Dev. (2019, December 9). *ARFoundation 2 image tracking with many ref images and many objects*. Retrieved from Unity Forums: https://forum.unity.com/threads/arfoundation-2-image-tracking-with-many-ref-images-and-many-objects.680518/#post-5260898

Apple. (n.d.). *Augmented Reality*. Retrieved from Developer Apple: https://developer.apple.com/design/human-interface-guidelines/ios/system-capabilities/augmented-reality/

Björk, S., & Holopainen, J. (2004). *Patterns In Game Design.* Rockland: Charles River Media, Inc.

Buckle, C. (2019, November 19). *AR vs VR: The Challenges and Opportunities in 2019*. Retrieved from Globalwebindex: https://blog.globalwebindex.com/chart-of-the-week/augmented-virtual-reality/

Burke, B. (2014, April 4). *Gartner Redefines Gamification*. Retrieved from Gartner: https://blogs.gartner.com/brian_burke/2014/04/04/gartner-redefines-gamification/

Burrows, L. (2019, October 2). *4D: increase the immersion*. Retrieved from Immersive Studios: https://weareimmersive.co.uk/blog/4d-increase-the-immersion

Chakravorty, A. (2018, October 9). *User Experience Design Principles for Mobile Augmented Reality Applications*. Retrieved from Medium: https://medium.com/inborn-experience/user-experience-design-principles-for-mobile-augmented-reality-applications-8ac0e5ebcdab

Christensson, P. (2016, August 18). *Augmented Reality Definition*. Retrieved from TechTerms: https://techterms.com/definition/augmented_reality

Cozi Inc. (n.d.). *Feature Overview*. Retrieved from Cozi: https://www.cozi.com/feature-overview/

Cubicle Ninjas. (2019, January 9). *2019 AUGMENTED REALITY TRENDS*. Retrieved from Cubicle Ninjas: https://cubicleninjas.com/2019-augmented-reality-trends/

Cubicle Ninjas. (2020, January 17). *2020 Augmented Reality Trends*. Retrieved from CubicleNinjas: https://cubicleninjas.com/2020-augmented-reality-trends/

Digi-Capital. (2019, January 15). *For AR/VR 2.0 to live, AR/VR 1.0 must die*. Retrieved from Digi-Capital: https://www.digi-capital.com/news/2019/01/for-ar-vr-2-0-to-live-ar-vr-1-0-must-die/

Engelmann, N. (2018). *Virtual Reality Gaming.* Antwerpen: Tectum.

Eşanu, E. (2018, November 15). *Gamification: Understanding The Basics*. Retrieved from UX Planet: https://uxplanet.org/gamification-understanding-the-basics-2bbcce365c33

Family Fabric Inc. (n.d.). *FamilyApp*. Retrieved from FamilyApp: https://familyapp.com/familyapp/

Fanguy, W. (2019, November 19). *How to make your first wireframe (+ video!)*. Retrieved from Invisionapp: https://www.invisionapp.com/inside-design/how-to-wireframe/

Farlex, Inc. (2015). *install(ed) base*. Retrieved from Farlex Dictionary of Idioms: https://idioms.thefreedictionary.com/Installed+base

Gladkiy, S. (2018, June 14). *User-Centered Design: Process and Benefits*. Retrieved from UX Planet: https://uxplanet.org/user-centered-design-process-and-benefits-fd9e431eb5a9

Google. (n.d.). *Fundamental concepts*. Retrieved from Developers Google: https://developers.google.com/ar/discover/concepts

Greenlight Financial Technology, Inc. (n.d.). *The tools you need to raise financially-smart kids*. Retrieved from Greenlight Card: https://www.greenlightcard.com/index.html

Guidev. (2018, April 18). *AR Portal Tutorial with Unity - ARCore Setup - Part1*. Retrieved from YouTube: https://www.youtube.com/watch?v=g78hQB8UKEM

Heuvel, B., & Riele, D. t. (2019). *Marketing Strategy of Family Quest.* Enschede: Family Quest.

IKEA. (2017). *Play Report 2017: A spark of play everyday.* Leiden, NL: Inter IKEA Systems. Retrieved September 24, 2019

Interaction Design Foundation. (n.d.). *User Centered Design*. Retrieved from Interaction Design Foundation: https://www.interaction-design.org/literature/topics/user-centered-design

InVisionApp Inc. (n.d.). *Mockup*. Retrieved from InVision: https://www.invisionapp.com/design-defined/mockup/

Kahoot DragonBox. (n.d.). *DragonBox Number*. Retrieved from DragonBox: https://dragonbox.com/products/numbers

Karagianni, K. (2018, December 6). *Optimizing the UX honeycomb*. Retrieved from UX Collective: https://uxdesign.cc/optimizing-the-ux-honeycomb-1d10cfb38097

Kiddie Kredit. (n.d.). *How It Works*. Retrieved from Kiddie Kredit: https://www.kiddiekredit.com/how-it-works/

Lamprecht, E. (2019, December 19). *The Difference Between UX And UI Design - A Layman's Guide*. Retrieved from Career Foundry: https://careerfoundry.com/en/blog/ux-design/the-difference-between-ux-and-ui-design-a-laymans-guide/

Lay, S. (2015, November 13). *Uncanny valley: why we find human-like robots and dolls so creepy*. Retrieved from The Guardian: https://www.theguardian.com/commentisfree/2015/nov/13/robots-human-uncanny-valley

Mauricio, J. (2018). *Family Quest: Getting kids to play in a digital world.* Bachelor thesis, Saxion University of Applied Sciences, Enschede.

Mobfish. (2019, June 28). *Immersion VR – Everything You Need to Know*. Retrieved from Mobfish: https://mobfish.net/blog/immersion-vr/#uncanny-valley-acceptance-limits-vary-from-person-to-person

Moran, K. (2019, December 1). *Usability Testing 101*. Retrieved from NN/g: https://www.nngroup.com/articles/usability-testing-101/

Morville, P. (2004, June 21). *User Experience Design*. Retrieved from Semantic Studios: http://semanticstudios.com/user_experience_design/

Nielsen, J., & Landauer, T. K. (1993, April 24-29). A mathematical model of the finding of usability problems. *Proceedings of ACM INTERCHI'93 Conference*, pp. 206-21.

OECD. (2018). *Children & Young People's Mental Health in the Digital Age*. Retrieved September 24, 2019, from http://www.oecd.org/els/health-systems/Children-and-Young-People-Mental-Health-in-the-Digital-Age.pdf

Oragui, D. (2019, February 1). *Mobile Augmented Reality in 2019*. Retrieved from The Manifest: https://themanifest.com/app-development/mobile-augmented-reality-2019

Punni, D. (2019). *Unity3d AR Foundation Tutorials For Beginners*. Retrieved from YouTube: https://www.youtube.com/watch?v=iRxDKCc6Z64&list=PLQMQNmwN3FvzCWfvCvq2AYh1CFnTlv2Es

Seal, A. (2020, January 23). *Top 7 Augmented Reality Statistics for 2020 [+ Use Cases]*. Retrieved from VXChange: https://www.vxchnge.com/blog/augmented-reality-statistics

Slater, M. A. (2003). A note on presence terminology. *Presence Connect, 3*.

Stefyn, N. (2019, October 24). *How Video Games Are Made: The Game Development Process*. Retrieved from CGSpectrum: https://www.cgspectrum.com/blog/game-development-process

Strickland, J. (n.d.). *How Virtual Reality Works*. Retrieved from How stuff works: https://electronics.howstuffworks.com/gadgets/other-gadgets/virtual-reality3.htm

Taylor, J. (2013, March 13). *Is Technology Creating a Family Divide?* Retrieved September 24, 2019, from Psychology Today: https://www.psychologytoday.com/us/blog/the-power-prime/201303/is-technology-creating-family-divide

Toca Boca. (n.d.). *Toca Hair Salon 4* . Retrieved from Toca Boca: https://tocaboca.com/app/toca-hair-salon-4/

Valdellon, L. (2019, October 4). *What is an SDK? Everything You Need to Know*. Retrieved from CleverTap: https://clevertap.com/blog/what-is-an-sdk/

Vito Technology. (n.d.). *Star Walk Kids ⭐ Become a Space Explorer ⭐*. Retrieved from Google Play: https://play.google.com/store/apps/details?id=com.vitotechnology.StarWalkKids&hl=en

## 15. Appendix

### Appendix I: 12 Competencies

**TECHNOLOGICAL COMPETENCES**

*1. Technical research and analysis*

Family Quest is considering improving its framework with the addition of mobile AR. As no one in the company has had extensive experience with this technology, it was my task to research how to implement it. As part of this project, I conducted research into the state and future of mobile AR and the ways its implementation can improve immersion, and user experience, with the goal of supporting future design choices and providing advice for the clients. This research can be seen in Theory chapter 7 of the report. As a result, I have gained a deeper understanding of the technology and have provided advice for the client regarding its implementation. I am glad I took the time to find the necessary information, as I feel much more confident recommending mobile AR to Family Quest based on those findings.

As the next step, Family Quest needed an SDK to develop an AR app and tasked me with picking a suitable one for the development of the prototype. I have analyzed several existing mobile AR SDKs, in terms of their functionality, limitations, costs, and supported platforms before presenting my findings and recommending Unity AR Foundation. The client was happy with my reasoning and approved my choice. The full SDK analysis can be seen in Appendix II. I am glad that my recommendation was accepted by the client.

Finally, as I have limited experience with mobile development and programming, it was necessary to conduct technical research to help guide me through the development process. I used the materials and documentation from the developers, official forums, and video tutorials to implement the basic functionality, as well as discover and fix issues. As a result, I was able to create a functional prototype in Unity using C#. I am especially proud of this, considering that I have never build a full prototype by myself.

**2. Designing, prototyping and realizing**

To fully test the potential of mobile AR, Family Quest needed a prototype. The goal of its development involved the implementation and testing of two main missions with all necessary AR functionality. I designed and developed that prototype following a user-centric design approach and going through the stages of wireframing, creating a mock-up, and prototyping. This method and stages were chosen based on the reasoning outline in chapter 7.5. This process is fully outlined in chapter 11.5. Throughout the process, I used the feedback of the client and the external guide to polish and improve the iterations, as well as the value requirements to ensure that the product would benefit the client. As a result, I created two iterations of the prototype which can be seen in Appendix X.

Overall, I am very happy with the final iteration of the prototype. It has all the basic features required, as well as pleasant visuals and UI, which were highly rated during the testing. Nevertheless, even though I fulfilled the initial goal, I wish I could have focused more on building on those basics to improve user experience and further polish the app, but the time limitations prevented that.

**3. Testing and rolling out**

Once the development phase has begun, I was faced with the challenges of AR implementation. It was my task to implement plane detection and image tracking in the Unity Engine. I made simple grey-box builds to test the technology and make sure it was functioning correctly before moving on to create complete scenes. In the end, I was able to make the first iteration of the prototype that was fully functional, thanks to those repeated tests and bug fixes.

After the first iteration was completed, it needed to be tested with the target group and reviewed by the client. The main goals of the testing were to gain feedback from the users, measure how valuable the app would be to Family Quest, and see what needs to be improved. As a result of the testing, I got positive feedback as well as some advice on how to improve it in the future. Some of that feedback was incorporated into the second prototype, while the rest was written down as recommendations for Family Quest. The breakdown of the feedback can be seen in chapter 11.6.

While I am glad about the constructive feedback and my recommendations, I wish I could have performed more tests and engaged the target audience more during the development. This proved to be challenging due to the limitations of social distancing, however, I think I could have done more, for example, using online conference tools.

## DESIGNING COMPETENCES

### 4. Investigating and analyzing

To design and develop a product for Family Quest, I had to investigate and analyze its framework, target audience, and the design of the existing apps aimed at them. To achieve that I conducted a literature review of existing Family Quest documentation, which can be seen in chapter 7.3. As a result of this review, the client and I formulated the value requirements of Family Quest (chapter11.1) that are further discussed in enterprising attitude section.

To further investigate the target audience, I use the methods outlined in the Methodology chapter 10. Those methods included UX research, which had a goal of learning about the target audience's awareness of AR and usability testing, mentioned in the testing and rolling out competence. UX research was based on the plan that can be seen in Appendix III and conducted through an online survey. Based on the findings (chapter 11.2), I was able to determine that most of the target audience have encountered mobile AR in one form or another, even though they have not realized that. Even though those findings were useful in creating appropriate set-up instructions, I wish I had also asked what mobile OS they were using. I should have spent more time determining the gaps in knowledge that could be filled with UX research.

The usability testing outlined before was not only helpful in determining the technical issues, but also ways to improve the design of the app. For example, I confirmed that the users were missing interactivity and would benefit from the addition of gamified goals.

Finally, as part of the design process, I analyzed several existing apps targeted at parents and children, to make sure my design would be suitable for them. This analysis can be seen in appendix VII. It eventually resulted in the creation of the stylesheet and helped determine the look and feel of the app. This was a necessary step in ensuring that the final design will be pleasing to the target audience and I am very happy with its results.

### 5. Conceptualizing

Once the need for a mobile AR app prototype was established, I have worked together with the client to create a concept. This concept was meant to be built upon the research done by Family Quest in the past, as well as fit within the Arthur's Quest storyline. There were several brainstorming sessions were previous ideas formulated during my SSS were discussed and evaluated (Appendix XI).

Based on that, the technical limitations of the chosen SDK, value requirements, and time limitations a design document (Appendix IV) was outlined. This document contained a description of both proposed missions, ways to further improve their designs in the future, a description of visuals, and a list of inspirations.

I think the final concept satisfied the requirements and utilized the strength of AR. There were many limitations to what could be implemented, both in terms of the technical aspect and the

story, so I am glad I was able to work within those limitations to develop an interesting product idea.

## 6. Designing

Once the concept was approved by the client, the design process could begin. The goal of this process was to create a wireframe and a mock-up to test the layout and design of the app, as stated in chapter 7.5. Using the design document and the design guidelines outlined in chapter 7.2.3, I moved through those stages to shape the concept into a final product. I developed a wireframe in Adobe XD to visually showcase the basic layout and content. Based on the feedback from the external guide the wireframe was adjusted and improved. As the next stage, I used the stylesheet to create a mock-up of the prototype, demonstrating the style and color scheme of the main UI elements. The more detailed description of the process can be seen in chapter 11.5. The resulting visuals were used in the development process. The design of the app continued to further change throughout the development of iterations, as I conducted testing and got more feedback. As a result, I created a product that with a few tweaks and improvements can be released to the market.

I am happy with the designs, both in terms of their visual representation, like wireframes and mock-up, and in terms of the final product. The testers were pleased with the UI and the ease of navigation within the app, showing it was successful.

## ORGANISATIONAL COMPETENCES

## 7. Enterprising attitude

Family Quest is a value-driven business, which is trying to get families to play together in this digital age. Therefore, it was my goal as a starting professional to not only implement mobile AR but do so in a way that furthers its mission. To fully understand the needs of the business, I had several conversations with the client and formulated the value requirements mentioned in the investigating and analyzing part. As a result, I could use those requirements to guide my design process, to test against during usability testing and help any future developers, making sure the final product will add value to the company.

However, to ensure that the addition of this new technology would also result in a profit, its forecasted future development and potential profitability were analyzed in chapter 7.1. This analysis showed that mobile AR is a growing market, with a lot of potential in entertainment and education. Therefore, I can conclude that the implementation of this technology is a great opportunity for Family Quest. New technological advances and a growing interest will provide many openings for the release of a profitable mobile AR app.

I find myself pleased with those findings and the process behind them, as they provide clear guidelines for the company. The value requirements were approved by the client and my analysis of the mobile AR potential will be used by the company in the future.

## 8. Enterprising skills

I have worked both independently and as part of the team during my graduation period. To develop a prototype, I had to solve technical problems, schedule and prioritize my own work using Scrum methodology as well as create innovative designs. The teamwork involved professional communication and participation in the decision-making process.

Part of the research and implementation of the AR app revolved around its commercial feasibility. I had to analyze existing SDKs in terms of their price and functionality to select the most commercially viable option. Based on my experience during the development I provided a further recommendation, advising Family Quest to invest in a paid SDK to cut down development time and gain access to better documentation and support.

Moreover, I used the information gathered during testing to recommend Family Quest to conduct further research into the mobile OS preferred by the target audience. Creating an app for the different platforms can give the company access to broader audiences and revenue. With that in mind, if the research confirms it, I recommend investing in the Apple Developer program. I believe I used my skills successfully to function as part of the Family Quest team and to create an innovative product.

**9. Working in a project-based way**
Outside of the AR app, Family Quest has been working on finalizing and releasing its first digital story – Arthur's Quest. I cooperated with Mark Boerrigter as the client and Melissa Wildschut, the other intern to prepare the story for the release. This involved creating artwork, relying on Melissa's feedback and expertise as the 2D artist, and learning new technical skills to improve the prototype of the interactive story. I set up an animation script that used sprite composites instead of full sprites, allowing to save space, and loading time. To create suitable sprites, I directed Melissa on how to export the images. Moreover, I worked with both Mark and Melissa to write 25 pages of dialogue for the story. As none of us are experts in storytelling, we had to rely on each other's feedback and take turns writing and improving the dialogue.
Even when I was working independently on the app prototype, I asked for the feedback of the team and external guide on the areas where their expertise was more prominent.
I am extremely happy about my role as a member of Family Quest. I have worked to deliver a great product and had cooperated with others in a productive and pleasant way.

**10. Communication**
Working with the Family Quest team required both face-to-face and online communication. In the beginning, Mark Boerrigter, Melissa Wildschut, and I had regular meetings in the office where we discussed our progress and provided feedback. Once that was impossible due to Covid-19 measures, we held at least semi-weekly Family Quest meetings over WhatsApp.
I am happy with our communication, although I think it has suffered due to the inability to see the team face-to-face. I realized that I had not updated the client on all aspects of the design and production in a timely manner, due to not being present in the same physical space. Additionally, the report and the document detailing AR implementation recommendations (Appendix II) can be used as an example of professional communication and presentation. The AR recommendations were designed to help Family Quest determine how to proceed, what further research needs to be done, and what investments can be worth considering. Moreover, this document is designed to help future Family Quest developers to implement and improve mobile AR. In all the written records I aimed to be organized and professional, providing helpful and clear information. I am happy with the final results of my written work and had received positive feedback from the client.

**PROFESSIONAL COMPETENCES**

**11. Learning ability and reflectivity**
Working in Family Quest has provided me with challenges in many areas of game development. I had to take on a role that I do not usually specialize in, such as game designer, UI artist, programmer, and even storyteller. I had to learn many new skills, like developing AR functionality using C# or implementing an audio manager. AR itself is a constantly changing and updating technology. Even when I was following a tutorial, I had to do research and read documentation, because the new version of AR Foundation made certain features presented in the tutorial obsolete. This was even more true when I had to adapt and change the content to match the specific requirements of the app. I was greatly helped by Christian Rietbergen whose

experience in game programming provided me with invaluable feedback. Based on his advice I reworked and improved several scripts, ensuring that they were not only functional but also efficient and clear. I learned how to use static scripts and coroutines, as well as many other functionalities that will be helpful in future development.

Similarly, I received feedback and advice from other people. Bob-Jan ten Cate helped me with the design process, providing recommendations during the wireframing stage. As a result, the prototype received an introduction from one of the story characters to tie them together. The semi-weekly meetings with the rest of the team, mentioned in the communication section, were also a good source of advice and helpful suggestions.

The final report is another example of iterative work and my attention to feedback. I created three versions of the draft report, which were reviewed by Taco van Loon and Mark Boerrigter, as the client. Based on their feedback I had shortened several sections, such as theory chapter, focusing on keeping only the most relevant information. I also made the final recommendation more specific and added some remarks regarding previous research into AR.

I believe that I was able to greatly deepen my skills, learn, and improve based on the feedback. Being able to keep up with the constant development was a big challenge and I am happy I was able to meet its demands. Nevertheless, I could have been more active in seeking out feedback and would aim to ask for it more often in future projects.

**12. Responsibility**

Family Quest designs and develops a product for parents and children. My responsibility was to create an app that would be safe and comfortable for people of all ages, including children of 4 to 7 years old. I had to emphasize with the target audience, imagining the space and scenarios in which the app will be used. The final design was created with their limitations and preferences in mind. This meant that, for example, the portal app provided the user with a placement indicator, which shows how big the virtual object will be. This, together with a message recommending an open well-lit area for play, allowed the user to pick the best spot to begin the experience. The portal itself was made to fit into an average living room. The spell cards were designed in a way that makes them readable on a computer screen, removing the need for printing and paper waste.

To ensure health and safety for both children and parents alike, they received a warning before the beginning of the portal mission, asking them to stay aware of their environment. Moreover, the play sessions were kept short to make sure the users will not become fatigued. While a lot of apps encourage the user to continue playing for longer periods of time, this would be ethically irresponsible for Family Quest, which is trying to get families to interact in the real world. As a result, it was shown in testing that both missions took under ten minutes to complete. I am happy with those results, as it means that even with an addition of extra goals and interactions, the playtime will not get too tiring.

Finally, I included comfort and safety recommendations into the document for Family Quest (Appendix II). This will ensure that future developers will have those guidelines in mind as well. I believe that I approached the design of the app responsibly, taking into account the target audience and their safety. I spent extra time polishing ang bug-fixing the final product making sure I delivered the best possible version. I wish I could more extensively test the app to ensure that there were not issues I missed.

## Appendix II: Family Quest Mobile AR Implementation

The document detailing AR implementation recommendation for Family Quest can be found here.

## Appendix III: UX Research Plan

### Background

Family Quest is a Dutch startup company working on an application that aims to help parent and children overcome the divide and start playing again. Family Quest is always searching for ways to enhance their formula of storytelling and bringing families closer together. Currently, they are looking into using Augmented Reality technology to enhance their product. Family Quest would like to know if the addition of AR would benefit their framework and enhance the users' immersion.

### Goals

Identify the target users' awareness of Augmented Reality.

### Research Questions

1. How much knowledge does the user have about AR?
2. Has the user used a mobile app with AR features?
3. Would they be interested in testing an AR app for Family Quest?

### Methodology

An online survey will be created to gather information. It will include several simple questions for both parents and children, regarding their knowledge and experience with AR. The survey will provide some examples of popular apps that utilize AR features, such as Snapchat, Pokémon Go, Wizards Unite or IKEA Place.

### Participants

These are primary characteristics of the study's participants:

Parents

- Age 30 to 45
- Interested in spending more time with their children

Children

- Age 4 to 12
- Own/use a smartphone

### Hypothesis

My hypothesis are as follows:

- 30-40% of the users have a clear understanding of what Augmented Reality is and can name an example of its usage.
- At least 50% of users have used an app with AR features, with even higher percentage for kids age 10-12.
- A lot of users don't realize that they have used AR features.
- Face augmentation and games are the most popular types of AR features.

## Appendix IV: Game Design Document

### Game overview

#### *Game Concept*

A mobile AR app with several missions that fits within the Family Quest framework. The missions are designed to accommodate several players using one device.

#### *Genre*

AR puzzle

#### *Target Audience*

- Children (4-7)
- Parents

#### *Game Flow Summary*

While the story Arthur's Quest, the players will be prompted to access the mobile app for special AR missions. The missions vary in gameplay and mechanics.

#### *Look and Flow*

An aesthetic of the app will match the style of the Arthur's Quest.

### Gameplay and Mechanics

#### *Portal Mission*

To begin the story and transport into the magical realm the players need to go through the magical portal.

#### Set-up

1. The players get introduced to the marker-less AR through the onboarding sequence.
2. The players move their phone around to locate the planes, once the planes are found, the placement indicator is shown.
3. The players can move their phone to pick the position of the portal, based on the basement indicator.
4. Once the position is selected, the players tap the screen to place the portal.

#### Gameplay

- The player can walk through the portal and look around the magical world.
- The virtual scene can be seen only through the portal, but once the players 'walk inside' it surrounds them, and the real world can be only seen through the portal.

Additional elements of gamification can be introduced to make the mission more immersive.

- Portal activation – the players need to activate the portal by performing a sequence of actions, like connecting the dots or tracing the pattern. Once the action is performed the players can go through the portal.
- Exploration – the players are prompted to find several objects inside the scene. This will encourage them to move and explore the virtual scene. It is important to make sure the scene remains stable during this and that the play time doesn't get too long.

### Visuals

The visuals of the mission need to match the style and art of the story.

- The portal needs to look like the portal on the game artwork, with hand drown textures.
- The virtual scene has to match the magical forest night artwork, with a similar color scheme and lighting.
- An addition of particle effects can enhance the scene.

### Examples

Some examples of magic portals in AR:
- **Wizards Unite**
- **Alice in Wonderland AR quest**
- **dARk: Subject One**

### Magic System

The players learn to perform magic spells, using enchanted cards created by Merlin.

### Set-up

1. The players print out or open the markers on another device.
2. The players are prompted to point the camera at the marker.
3. Once the app detects the marker, the gameplay is initiated.

### Gameplay

The players need to complete the spell to activate it.

- A glowing point will appear at one corner of the card, prompting the player to tap it.
- Once the player taps the point, they will be prompted to drag their finger across the screen towards the next point, connecting the dots with a glowing line.
- Once all the dots are connected, the spell is complete.
- Each spell card has a different sequence of dots.

### Visuals

The spell cards are based on the Merlin's card trick art piece.

- The cards themselves match Merlin's color scheme of gold and purple, with intricate symbols.
- Each card has a symbol that corresponds to the card's function – fog cloud, rain or healing.
- The spells are shown through particle effects.
- The symbol will glow brighter for a few seconds, disappear and instantiate the particle effect of the spell.

### Examples

Some examples of casting spells:
- **Wizards Unite**
- **Book of Spells**

Example of an arcane circle effect:
- **Magic Circle Wireless Charger**
- **Magic Circles and Shields**

## Appendix V: Introduction to Usability Testing (Dutch)

### Koning Arthur – AR Missies Test

*Introduction*

Beste ouder, dankjewel voor je deelname aan onze test!

Lees voordat je begint de instructies in dit document.

De test duurt in totaal ongeveer 30-60 min.

Succes en veel plezier!

*Het doel van Family Quest*

In een wereld die steeds sneller en steeds meer digitaal wordt, willen we bij Family Quest juist echte ervaringen en creativiteit stimuleren binnen families. Daarom hebben wij een speelse mix van verhalen en activiteiten ontworpen waar iedereen een rol in heeft.

Uit onderzoek blijkt namelijk dat wanneer ouders en kinderen echt samen spelen en spannende verhalen ervaren ze een betere band met elkaar ontwikkelen. Dit leidt vervolgens tot meer ontspanning en een beter begrip van elkaar in het gezin.

We snappen natuurlijk dat geen enkele familie hetzelfde is. Daarom hebben we onze avonturen zo ontworpen dat verschillende leeftijden, gezinssamenstellingen en leefsituaties geen probleem zijn. Hiermee leveren we een goed fundament dat volwassenen gemakkelijk zelf naar hun eigen situatie kunnen vertalen.

Dus, ga nu op zoek naar het kind in jezelf en geniet samen van het avontuur!

Meer informatie vind je op https://www.familyquest.nl/

*Het doel van de test*

Family Quest is altijd op zoek naar het verbeteren van de ervaring. Nu zijn we op zoek hoe Augmented Reality onze avonturen nog leuker kunnen maken.

Dit prototype is het resultaat van onderzoek en ontwikkeling door een afstudeer student. Het bevat twee missies die horen bij het verhaal van de jonge Koning Arthur. Dit verhaal is nog in ontwikkeling, maar is binnenkort verkrijgbaar!

*Voor het testen*

Voordat je begint met testen moet je eerst de app installeren met behulp van de instructies hieronder.

Voor de tweede missie heb je een een "Spreukkaart" nodig. Deze zit als bijlage bij je mail en kun je printen of op een PC of laptop scherm tonen.
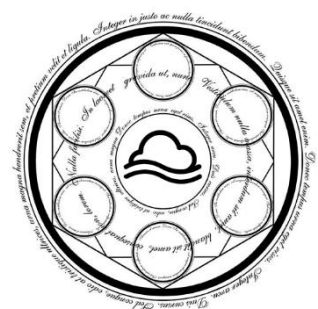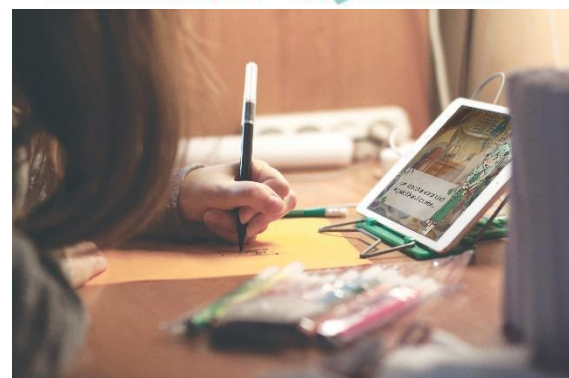
*App Installatie*

Deze app kan alleen gespeeld worden op een android apparaat met android 7.0 of hoger.

1.  Ga naar instellingen → beveiliging (of instellingen → applicatie op oudere apparaten) en zet dan een vinkje in het hokje naast onbekende bronnen. Dit moet u misschien bevestigen met een OK.

2.  Open op uw apparaat de link naar de app.

3.  Download de app en open dit wanneer dit gevraagd wordt.

*Tijdens het testen*

Er zijn twee missies die je kunt proberen:

1)  Het Magische portaal - plaats een portaal in je omgeving en ga de magische dimensie in

2)  De Spreukkaarten - gebruik de spreukkaart om een magische mistwolk te maken

Probeer bij te houden hoe lang je over de missies doet. Laat uw kinderen de leiding nemen waar mogelijk en ondersteun ze indien nodig.

Let op momenten van frustratie of opwinding tijdens het testen. Het is een prototype, dus geen gereed product. Als iets niet goed werkt, laat het ons weten, zodat we dit kunnen verbeteteren. Bedankt alvast!

*Na het testen*

Vul na het testen aub de volgende vragenlijsten in:

Ouders: https://forms.gle/qy7RQyH4ya8Tp53g6

Kind(eren): https://forms.gle/NdKWLpaDZQ3W18jp8

Elke ouder en kind (als er meerdere zijn): willen julie zo vriendelijk zijn om allemaal je eigen vragenlijst in te vullen?

Dankjewel voor je deelname! Je krijgt een speciaal plaatsje in ons avonturen universum!

## Appendix VI: UX Survey

### Parent Section

| Wat is je leeftijd? | Hoe bekend ben je met de technologie Augmented Reality (AR)? | Heb je wel eens een app gebruikt met augmented reality, zoals de voorbeelden van hierboven? | Zou je Family Quest willen helpen door een Augmented Reality toepassing te willen testen? |
|---|---|---|---|
| 36-40 | Ik ben dol op de technologie en ben op de hoogte van de laatste ontwikkelingen | Ja | Ja |
| 36-40 | Dit is de eerste keer dat ik er over hoor | Ja | Ja |
| 36-40 | Ik weet er een klein beetje van, ik ken apps die de technologie gebruiken | Ja | Ja |
| 36-40 | Ik weet er een klein beetje van, ik ken apps die de technologie gebruiken | Ja | Ja |
| 41-45 | Dit is de eerste keer dat ik er over hoor | Ja | Ja |
| 36-40 | Ik weet er best veel van en kan voorbeelden benoemen van apps die AR gebruiken | Ja | Ja |
| 31-35 | Ik weet er best veel van en kan voorbeelden benoemen van apps die AR gebruiken | Ja | Ja |
| 36-40 | Ik weet er best veel van en kan voorbeelden benoemen van apps die AR gebruiken | Ja | Misschien |
| 36-40 | Dit is de eerste keer dat ik er over hoor | Ja | Misschien |
| 46-50 | Ik weet er best veel van en kan voorbeelden benoemen van apps die AR gebruiken | Ja | Nee |

### Child Section

| Hoe oud ben je? | Heb je wel eens gehoord van Augmented Reality? | Heb wel je wel eens een app gebruikt die je gezicht verandert, zoals Snapchat? Of een app waarbij er fantasiewezens in je camera te zien zijn, zoals Pokemon Go? |
|---|---|---|
| 5-7 | Nee | Ja |
| 8-10 | Nee | Ja |
| 2-4 | Nee | Nee |
| 8-10 | Niet zeker | Ja |
| 2-4 | Nee | Ja |
| 2-4 | Nee | Ja |
| 2-4 | Nee | Ja |
| 11-12 | Niet zeker | Ja |
| 5-7 | Nee | Ja |
| 2-4 | Nee | Nee |
| 5-7 | Nee | Ja |
| 2-4 | Nee | Ja |
| 8-10 | Niet zeker | Ja |
| 2-4 | Nee | Ja |
| 5-7 | Nee | Ja |
| 2-4 | Nee | Nee |
| 8-10 | Niet zeker | Ja |

## Appendix VII: App Analysis

To design an app that is both easy to use and aesthetically pleasing to the target audience, the research into the existing apps was conducted. The design of four mobile apps aimed at families and designed to be used by both parents and children were analyzed to see what design choices are made when the target audiences' ages are can vary significantly. Then, as the AR application is meant to mainly appeal and immerse children, with parents supervising and sharing the experience, four apps aimed specifically at children were analyzed. The apps with the themes of exploration, learning about the real world, encouraging curiosity and creativity were picked.

To make sure that the analyzed apps were well received, only the apps with a rating above 4.0 were selected.
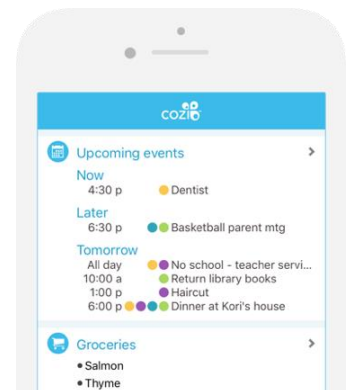
### Cozi Family Organizer

*Rating: 4.8 on App Store*

Cozi is an organizer for families, with a shared family calendar, reminders, grocery list and more. It is designed to help families keep track of everyday activities and tasks. Cozi is a "3-time Mom's Choice Award Winner and The TODAY Show "must-have app" for a better life" (Cozi Inc., n.d.).

*UI Design:*

Cozi has a simple flat UI design. It uses mainly light colors, with a white background and pastel blue highlights. Additionally, the app employs brighter colors to color code the calendar entries per family member. The icons are circular, with blue background and white minimalistic symbols.

### FamilyApp

*Rating: 5.0 on App Store*

FamilyApp is a private messenger specifically designed for families, with contact directories, chat functionality and groups. It allows the users to safely organize their "family-related data", be it photos, videos or calendars. The app is end-to-end-encrypted and safe to use. (Family Fabric Inc., n.d.)

*UI Design:*

FamilyApp's UI is simple and flat. The colors of the background and buttons is white, with deep green highlights and icons. The icons and buttons are rounded, with thin lines.

### Greenlight

*Rating: 4.8 on App Store*

Greenlight app provides a pre-paid debit card for kids and teenagers that can be managed by parents through the app. Parents can set chores and allowances, control which stores money can be spend and see real-time notifications of each transactions. The children can monitor their balance and set savings goals (Greenlight Financial Technology, Inc., n.d.).

*UI Design:*

The design of the Greenlight app is simple, with grey and white colors. It has flat buttons that cast light drop shadows. The buttons themselves are rounded with thin outlines. The green is used for highlights and selected icons.
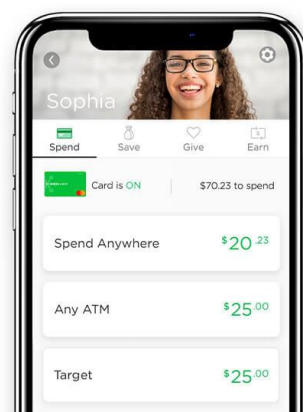
### Kiddie Kredit

*Rating: 5.0 on Product Hunt*

Kiddie Kredit is an app that aims to teach children about credit scores, by simulating one based on the kid's chores and spending. Based on the 'kredit' score, allowance or non-monetary rewards can be provided by the parents (Kiddie Kredit, n.d.).

*UI Design:*

The app design is very simple and flat. The background is white, with teal highlights. The buttons and icons have thin, rounded grey outlines. Colorful illustrations of animals are used to symbolize the children.
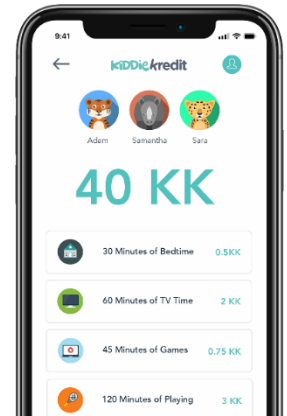


### Toca Hair Salon 4

*Rating: 4.0 on Google Play*

Toca Hair Salon 4 is a creative digital salon where the player can use different styling tools to edit the looks of different characters. There are no set goals, levels or high scores, instead the game challenges the player to use their imagination and allows them to play the way they want to (Toca Boca, n.d.).

*UI Design:*

The app has minimal UI, as most tools and options are presented through the in-game objects. The existing buttons are brightly colored, simple and flat, with white outlines and white icons. The icons themselves are rounded and concave. The shop and main menu button are located at the top of the screen. The buttons in the main menu are animated and have cell shading.



### DragonBox Numbers

*Rating: 4.5 on Google Play*

DragonBox games are designed to teach children through an interactive digital experience. DragonBox Numbers aims to show children from 4 to 8, what numbers are, how they work and what can be done with them. The app contains four different types of activities, with each one focusing on building understanding through gamification. (Kahoot DragonBox, n.d.)

*UI Design:*

The app uses colorful backgrounds and illustrations with white UI. The font is playful and childish, with letters varying in thickness, rotation and offset from the ground line. The icons are colorful, with white cartoony symbols. Many elements of the interface are animated, for example, the icons for the next levels pulsate to gain the child's attention and animated hand shows how to drag the coins to unlock new stages. The buttons are geometric, but with uneven borders. The main in-game buttons are located at the top, with the menu positioned at the top center.
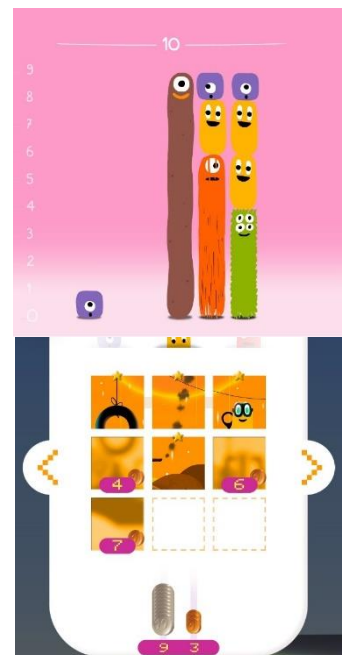


### Star Walk Kids

*Rating: 4.3 on Google Play*

Star Walk Kids is an app designed to explain the basics of astronomy to children. It contains information about stars, constellations and planets, as well as other celestial objects. The app uses animated movies to explain the basic concepts in an accessible language (Vito Technology, n.d.).

*UI Design:*

The interface design of Star Walk Kids is simple and cartoony, matching the style of its illustrations. The buttons of the app are cell shaded with one or two colors and highlights, they have white outline and drop shadow.  Most of the icons are simplistic and rounded. The in-game buttons are in different corners of the screen, with the bottom left corner reserved for information pop-ups, while the settings button is in the center on the left.

## Dr. Panda – Learn & Play

*Rating: 4.5 on Google Play*

Dr. Panda – Learn & Play app is designed to encourage 8-year-old and younger kids to learn and develop through play. The app has a collection of games, interactive storybooks and videos, aiming to introduce important live skills and build emotional intelligence. It can teach children things like simple math, letters, days of the week and much more ( Dr. Panda Limited, n.d.).

*UI Design:*

The game has colorful cartoony illustrations designed to appeal to young children. The buttons match this style with simple white icons, orange background and white borders with light cell shading. The return button is positioned at the top left, while the menu button is on the bottom right. The game selection menu uses rounded images with white borders for different games.

## Conclusion

The apps aimed at families had a significantly different design from the ones aimed at children specifically. The family apps had simple flat UI design with white background and blue or green highlights. This could be explained by the fact that most family apps seemed to be designed for organization, chores and pocket money tracking.

The apps aimed had a more colorful UI, matching the cartoony style of illustrations designed to appeal to children. Most of the apps used colored buttons with white outlines, either flat or with cell shading. Several elements of the interface were animated to highlight what should be pressed next or provide instructions. Some elements of interface became part of the game themselves, such as styling tools in Toco Hair Salon 4.

Overall, it is clear that to appeal to children and spark their curiosity it is better to create UI that matches the style of the game itself and is bright, simple and cartoony.  Animated UI can help guide them through the app and provide information.

## Appendix IX: Usability Testing

Results of the parent survey can be seen here.

Results of the child survey can be seen here.

## Appendix X: Proof of Product

Android builds and markers can be downloaded here

The first iteration is Arthur's Quest AR v0.9.01 and the second iteration is Arthur's Quest AR v1.0

The video and photos of the prototype can be seen here.

## Appendix XI: Previous AR Research

The document outlining AR research conducted by me during the SSS can be found here.

The document outlining the ideation phase created during SSS can be seen here.