Universitetet i Agder

MM - 500 - Master Thesis

DinosARs - Learning with the help of augmented reality

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Abstract

A two-dimensional way of interacting with learning material has been the norm for a long time. We've read books, taken notes and been taught from a blackboard since youth, and has for most of us worked out just fine, but we are all different. We have those visual learners, those who learn through seeing things, auditory learners, those who learn best through hearing and kinesthetic learners, those who learn by doing. Augmented reality can provide many unique affordances that can deliver a learning experience that can benefit all learning types. Augmented reality can utilize both visuals, sound, and interactivity. It can also let the student take ownership of their own learning experience. This paper will provide an introduction to the technology, the development of an augmented reality application and testing it in real life situations.

Keywords: Augmented reality, virtual reality, application development, learning, primary school

Preface

The interest for augmented reality came about when Pokémon Go was released in 2016. As a person who finds new thinking, technological advancement and games fun, this was back then, something out of the ordinary, refreshing and innovating.

I did not, however, have any experience in the development of AR until 2018. This was the last semester before the start of the master thesis and I wanted to start developing something that could fuel my interest in technology and innovation for years to come. It was at this point, I started thinking about AR and its possibilities. I wanted to broaden my horizon within the field and start specializing at something, which ended up in the first iteration of the application DinosARs.

The project throughout has been a journey full of learning and new knowledge. I've gotten to see different possibilities that the technology has to offer and the joy that it brings to its users, but also the challenges that it provides, both in terms of development and where it can fit in.

In the end, I would not have been able to deliver my thesis at the current level without the help of my supervisors, who helped me through uncharted waters, so thank you.

I hope you will enjoy my thesis.

1 Introduction

Augmented reality (AR) is to me, a fascinating, fun, and engaging technology. It enables the user to experience a whole new world within our own. By recognizing a surface, you can, with the help of a digital device project a 3D model into our world. This technology can make it easier to envision complex things that would be hard to show only on paper.

It is a technology that has been around for a long time[8], but has not started to mature until recent years with the help of more powerful devices and software. This enables the use of AR technology in a broad array of fields, but in this case, we will focus on educational purposes.

In Bill and Melinda Gates annual letter of 2019 [9], Bill talks about how textbooks are finally becoming obsolete. He also says that; "Text can't figure out which concepts you understand, and which ones you need more help with. It certainly can't tell your teacher how well you grasped last night's assigned reading"[9].

With the help of technology, it is easier to find the information you are looking for, have fun while playing games that utilize gamification principles and watch educating and exciting video about learning material. AR is another technology in this step and enables a vast range of tools. AR is not something that replaces a teacher but may enable the teacher to enhance your learning experience, and more easily give feedback. The student may also take more ownership of their own learning. AR is something that is not only a technology but can also be seen as a learning concept, which may be more productive for educators[5].

It has been asserted that AR for educational purposes is one of the areas where AR might shine [10]. It may have the possibility to find a home in education with enough research done to the effect of AR and its learning outcomes. As stated in a recent literature review by Dunleave and Dede [11], "Due to the nascent and exploratory nature of AR, it is in many ways a solution looking for a problem. More accurately, AR is an instructional approach looking for the context where it will be the most effective tool amongst the collection of strategies available to educators".

By the end of this thesis, hopefully, a few gaps in the lack of research done to AR may have been filled.

1.1 Background

This paper is based on a project that was started in the course MM - 503 - Project, where I developed an AR pamphlet called DinosARs. This pamphlet was meant to teach the user about dinosaurs and the world they inhabited. This was made without any previous knowledge of the development of augmented reality and in the interest of broadening my horizon within the field as this is something that I feel is something that will be relevant in the future to come.

In this paper, the idea is further developed and tested.

1.2 Motivation

My motivation when starting the MM - 503 - Project was to fulfill my curiosity and interest in AR. I also wanted to learn more about the development, as it was something I had never done before. After learning more about the process, I also wanted to find out if what I was now able to create, could improve the performance of students in a real-life setting and measure the performance of the technology. AR has, in my own opinion, a vast potential when it comes to learning, and this is something that I wanted to investigate.

1.3 Goal of the research

The goal of the research is to develop the DinosARs concept further and try to utilize it in a real-life environment. The test subjects will mainly be children in the age group of 8 to 14.

1.4 Structure of the research

Before delving into the paper, I want to give a small explanation about what the different sections of the paper contain.

The first section of the thesis is a literature review. This section will talk about the different learning theories that AR can utilize. It will also talk about the technology that is AR and how it can be used in primary schools.

The second section of the thesis will explain what methods and tools that were used.

The third section of the thesis will talk about the context of use. This means what kind of environment the application is going to be used in, defining the requirements, the users, and a small scenario.

The fourth section will explain the construction of the application and how each of the tools was used to create the finished product. It will also go through the different iterations that the application had.

The fifth part will test the application in a controlled environment and go through the different results that the testing gave answers to.

The sixth part will talk about the different findings that were discovered during the thesis, development, and testing of the application.

The seventh and second to last part of the thesis will talk about what kind of future work that can be done to the thesis, the application, and how to use AR technology in future environments and settings.

Lastly, we will conclude the thesis with a conclusion.

2 Literature review

A learning style is a concept of having a theory that takes account of the differences in individual learning. This means that we are all different with different needs and ways of learning. Some learn by repetition, some learn by seeing, some learn by discussing, some learn by doing, some even learn by building a memory palace. Just as people vary, so does learning styles.

Based on a study by Liu, Dede, Huang, and Richards [12], the absence of learning theories is common when developing VR products for education. One could argue that this also applies to AR as they are both parts of the reality spectrum. One could also then argue that a learning theory that would work in a VR environment would also work in an AR environment. The application of VR technology in the field of education is still in the early stages of testing but has still been brought into the conventional classroom on a large scale. Liu, Dede, Huang and Richards explain [12] how one of the significant challenges to develop and use VR for education, is understanding the pedagogical and learning theories that should inform the design and use of these VR systems, and that the first key theoretical basis for applying VR on education, is constructivism. They also explain[12] how constructivism suggests to place students at the center of learning and teaching, not only asking students to be the active body of information processing and meaning construction but also requiring teachers to be the guide rather than the instructor of learning. The context, activities, and social interactions in the learning environment should with constructivism also keep challenging the learners' experience stored in their minds, promoting the construction of new knowledge. From this, you could implement a series of strategies extended from constructivism such as situated learning, experiential learning, and collaborative learning.

The second learning theory that Liu, Dede, Huang, and Richards thinks that apply to virtual learning[12] is autonomous learning or also known as self-directed learning. This is referred to a situation where learners set their learning goals, select their learning methods, minor their learning progress, and assess their learning outcomes when acquiring knowledge. According to this theory, the process of the students autonomic exploring for knowledge construction is more important. In this scenario, the teacher should play a guiding role. Here, the students should use the feedback from teachers or the environment to understand learning targets and acquire the ability of problem-solving. VR technology can provide resources necessary for autonomous learning, allowing the students to select suitable learning environments based on their learning requirements or the ability to practice on an unlimited number of repetitions. Hsu [13] also states in her thesis that self-directed learning is one of the 21st-century core competencies and supports lifelong learning in the future, not only to be used within AR learning environments but learning environments in general.

2.1 Experiential learning model

The theory of experiential learning was proposed by David Kolb. Experiential learning focuses on learning from experience and after acquiring that experience, reflecting on it. According to an article by Yonghui and Hui [2], Kolb extended the research based on John Dewey and Pfieffer and Jones, theorizing that learning takes place through a four-stage continuous cycle.

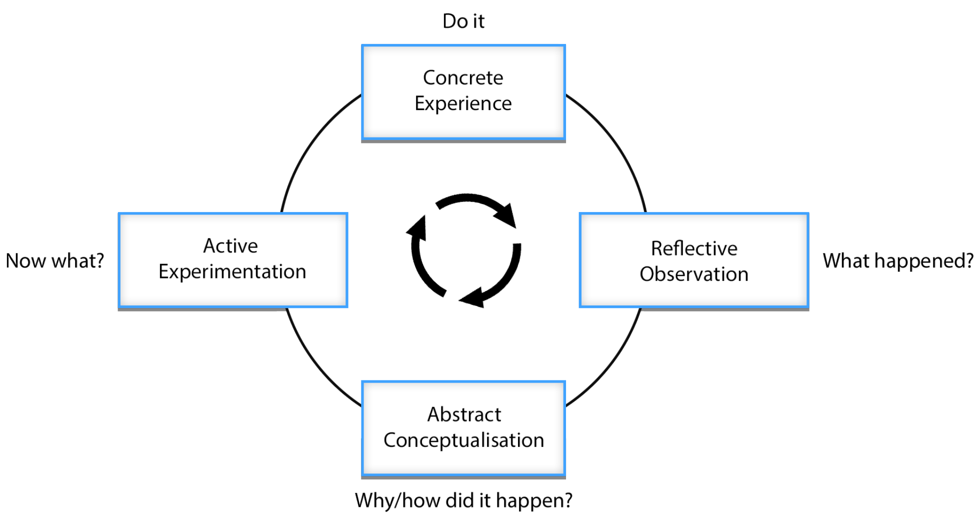


Figure 1: Kolbs experiential learning model [1]

The first phase of the cycle is concrete experience, followed by reflective observations which stimulate abstract conceptualization that finally provides ideas for active experimentation. According to Yonghui and Hui[2], this is the cycle that stimulates learning and defines the process as holistic and integrative.

Yonghui and Hui[2] also explain how experiential learning a natural fit for non-formal education. In non-formal education, there are no set structures or intentional processing. You take more ownership of your learning. Individuals learn alone, from one another or the environment, with or without a teacher, guide, or mentors supervision. For a comparison, see Figure 2 on the next page:

Formal Education	Non-formal education
Educational setting	Anywhere
Mandated attendance	Voluntary attendance
Mandated hours	Hours to fit learner
State-set curriculum	Youth-set curriculum
Teacher as licensed expert	Adult volunteer as facilitator
Learner earns grades or diploma	Learner moves through program goals and earns tangible rewards

Figure 2: Formal and non-formal education[2]

Utilizing a non-formal education is something that, in my opinion, suits DinosARs very well. It is an application that can be used at any time, anywhere, with anyone.

2.1.1 VARK model

According to Neil Flemings VARK model, there are four different categories that you as a learner can be divided into based on your preferences for visual, auditory read/write or kinesthetic learning style. As explained in a report by Yoon and Chandrasekera [3], Neil Flemings VARK model is utilized by many researchers and will be the main learning method used in this article as AR is mostly a visual and kinesthetic learning tool.

Figure 3: VARK Model [3]

2.1.2 Multimodal learning

In an environment of multimodal learning, the learner is presented with a learning material that utilizes more than one of the senses presented in the VARK model. According to a study [14], students who are presented with more than one sense, have an easier time learning and improves attention. This can lead to improved learning performance, especially for lower-achieving students. The study also discusses the benefits of visualization in learning environments;

- Promoting learning by providing an external representation of the information
- Deeper processing of information
- Maintaining learner attention by making the information more attractive and motivating, hence making complex information easier to comprehend.

According to Lujan and Dicarlo [15], medical students prefer multiple learning styles to the point where only 12.5 percent of male participants preferred a single mode of information presentation. On the other hand, 54.2 percent of female participants were satisfied with only one mode of information presentation. Based on this information, based on this information, we can see that this is something that suits DinosARs, as the application utilizes more than one mode of presentation. DinosARs have elements of both sounds, interaction, 3D models, and text which could attract both visual, auditory, and kinesthetic users and could help students learn in a way that they find the most comfortable.

2.1.3 Paper

For this project, the use of paper with images of dinosaurs and text is still present. In this digital day and age, this could have been discarded, and it could have only been presented only with a single QR code. So why do we still hang on to paper? According to a study by Sulaimi and Al-Shihi [16], it was reported that students who read from a screen read 36 percent slower than those reading from paper. They also conclude that digital technologies have altered the way we think, shortening our attention span, which can make it harder to stay focused. The reading became more fragmented, sporadic, and haphazard, and readers became more prone to skim scan and scroll for keywords they were looking for. According to Sulaimi and Al-Shihi, a result from 19 countries and 10,000 students, showed that students had a consistently strong preference for print format. In a study by Naomi Baron[17], students also enjoyed the characteristics of books, like the smell of paper, and that they could "see" and "feel" where they were in the text. In my own opinion, being able to interact with a physical material as well as digital, may strengthen the multimodal way of learning. Kinesthetic, as well as read/, write learners may have an advantage of also using paper.

2.2 Augmented reality

Augmented reality or AR is a technology that allows the user to use a handheld device like a smartphone or a head-mounted display like Hololens to augment the real world with digital elements. According to a Ph.D. dissertation by Gjøsæter [18], augmented reality must have three specific properties to be qualified as augmented reality. These three attributes are:

1. It should combine the real and the virtual.
2. The augmentations should be interactive in real time.
3. They should be registered in three dimensions.

In the reality spectrum, based on Milgram's design [4], it is positioned close to reality. Augmented reality is the ability to overlay graphics onto the physical world. If you go to the other end, you end up with virtual reality. This virtual reality is a world where everything is digitized. In between, you have mixed reality. Mixed reality utilizes both techniques, and can display a digital object in the real world, with an environmental understanding.

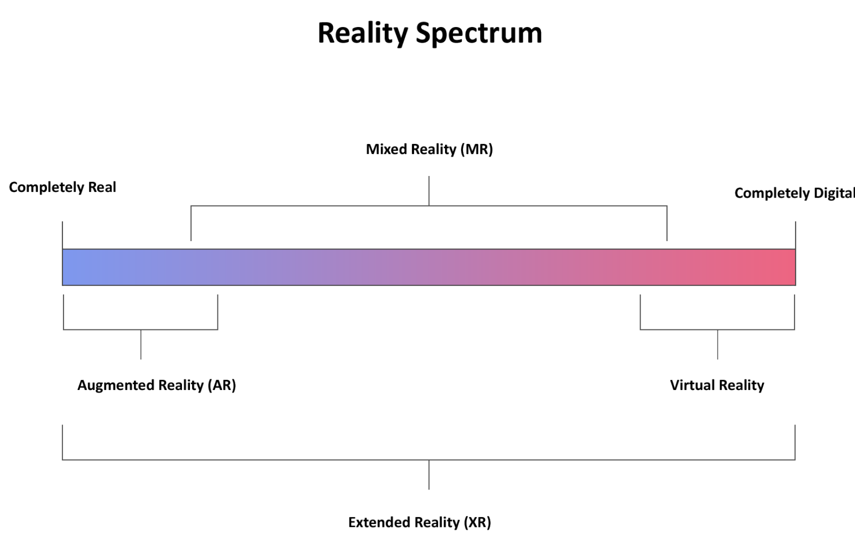


Figure 4: Reality Spectrum [4]

There are three main physical components needed to use AR. A camera, a display, and a computational unit. The camera to view the world that is supposed to be augmented, a display to display the digital and real world merged together, and a computational unit that handles the software. This marker is then uploaded to a Vuforia database, before being fed into Unity.

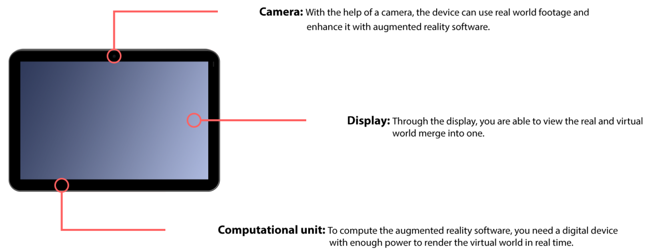


Figure 5: Three main components needed to use AR

In this case, the software that is used is Vuforia, which is a software development kit (SDK) for Unity. For Vuforia to recognize the target you want to augment, you need a marker that the camera can easily distinguish from other elements: a recognizable marker. On top of this marker, you can, in Unity, place the digital features you want to display when the software recognizes the marker through the camera.

Figure 6: AR needs a trackable object

2.2.1 Advantages of augmented reality

AR can provide a way of interacting with physical materials that we know and are used to in a whole different way. It can also make it easier to visualize scenarios, materials, objects, and experiences that we would not otherwise be able to envision in an easy way. Tasneem Khan, Kevin Johnston, and Jacques Ophoff explain how it can enable the user to experience scientific phenomena that are not possible in the real world, such as certain chemical reactions, making inaccessible subjects matter available to students. This type of learning experience can encourage thinking skills and increase conceptual understanding of phenomena that are either invisible or difficult to observe as well as correct any misconceptions [5]. They also explain how the cognitive workload may be reduced by integrating multiple sources of information. It may also then encourage multimodal learning.

AR has the potential to afford the user several benefits. Based on a study on the affordances of AR for educational purposes[19], the main affordances are:

- The usage of 3D models to more easily observe and model physical phenomena.
- By utilizing AR, you are able to represent concepts and events that would otherwise be invisible or hard to observe.
- Real-life problems can be situated in a collaborative instructional scenario.
- AR could potentially enhance the learner's sense of presence, immediacy, and immersion.
- Ar could make a connection between learning in a formal and informal setting.

As an AR application, DinosARs also has the ability to continually get updated as new information surfaces or new features are invented. The means that AR books will always be up to date with the newest features available. This may save money, where AR book owner will not have to buy the newest edition, as the book they have will update itself. It may also be cleaner to the environment, as fewer books will have to be produced. It will also be easier to have one book in several different languages, where the AR text changes depending on your preferred reading language.

2.2.2 Motivation

Getting work done, can in some cases be tiresome, difficult and boring. To get these kinds of things done, being properly motivated is key. Robert explains [20] how a student who is motivated will be engaged in the learning process and obtain more from the educational experience, whereas an unmotivated student will gain little from a course and the learning experience will be minimal. For a student to be motivated, they have to have a vested interest in the subject. Students need to feel that the work is meaningful, and there needs to be a conceptual understanding of the content. According to Tasneem Khan, Kevin Johnston, and Jacques Ophoff [5], students who are academically motivated tend to engage, persist and expend effort to complete tasks compared to unmotivated students. A lack of motivation could be a major obstacle to learner success, emphasizing the importance of creating and sustaining motivation.

For the student to more easily be motivated, the application should try to motivate the user intrinsically. Key factors that influence intrinsic motivation are; challenge, curiosity, control, and fantasy[5]. Willpower and a positive attitude are also required to sustain motivation for learning[5]. Intrinsic learning tries to make the student participate and engage without external forces trying to pressure and reward. Participation is influenced based on the desire of experiencing the fun, challenge and uniqueness of the academic activity[5]. Studies have shown that AR positively motivates the student, where the increased student motivation may be largely attributed to the elements of curiosity, fantasy, and control presented in the usage of AR technology [5].

Based on the attention, relevance, confidence, and satisfaction (ARCS) model by Keller as seen down below in figure 7 [5], the design of the AR technology and the DinosARs application, should attract the students' attention. It should also be relevant to the student, and the student must be confident with the technology and feel satisfied using it[5].

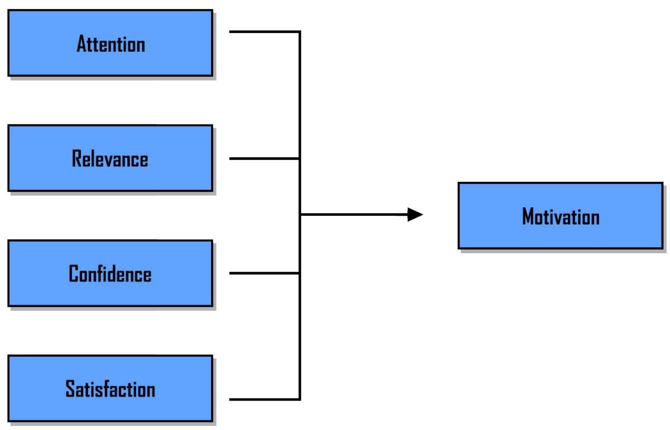


Figure 7: Keller's ARCS model [5]

2.2.3 Downsides of augmented reality

The appliance of AR might sound like to solution to all of our problems, but there are things to consider. Not everyone learns in the same way, and AR is not a solution that suits everyone's needs. And as mentioned, you also need a handheld device and depending on the model and operative system; not all applications may be supported. AR is also a reasonably technological learning concept, and not all teachers are happy or competent to use new technology or learning concepts.

Based on a study from 2014 [21], who in total studied 32 articles from 2003 to 2016, it was reported that students might feel frustrated if the application does not work correctly, or if it is difficult for the app to read the target markers correctly, which might end up in a bad user experience. Another limitation reported is that an AR application is usually designed for a specific purpose or a particular field of knowledge, which does not make it very flexible. It also reported that students might pay too much attention to virtual information, which might hinder the full learning experience.

The study[21] also concluded that there were few to no studies about AR for educational purposes, especially early childhood education, which should encourage researchers to explore the field. Most articles emphasized the emotional and effectiveness or AR, like motivation, attitude, engagement, enjoyment, and performance.

A study by Da Silva, Teixeira, Cavalcante, and Teichrieb from 2019 [22], crawled through forty-give works from an open-source IEEE, ACM and Science Direct database. They then found out that even though most studies about AR provided positive outcomes, most of the studies did, however, lack the involvement of the teacher and the use of multiple metrics to evaluate educational gains.

Augmented Reality is a technology that has been around for a long time, and has been studied for over 40, but has in the last decade only began to be formally evaluated [22]. The reason that AR has been around for so long without being user evaluated may be a lack of knowledge of how to properly evaluate AR experience and design experiments [22]. Da Silva, Teixeira, Cavalcante, and Teichrieb [22] claim that there seems to be a lack of understanding regarding the need for doing studies and the right motivation for carrying them out.

Tasneem Khan, Kevin Johnston, and Jacques Ophoff also explain [5] how the combination of real and virtual objects may cause confusion, as the students may face difficulty navigating between fantasy and reality. It also requires the students to perform multitasking, as the students need to engage with large amounts of information and multiple technological devices to accomplish complex tasks. This may result in cognitive overload and a feeling of being overwhelmed or confused[5].

One thing that one has to take in consideration when using technology, especially new technology, is that stability may not be guaranteed. This means if the applications used are not well designed in terms of interface, guidance, and stability, this may result in the technology is too complicated for the user[5].

2.3 Applying augmented reality in primary school education

AR is a technology that can be applied to several environments, with the possibility to change the way we do things. AR in as an educational concept is still in its infancy.

One fascinating and exciting place augmented reality can be applied in the classroom. AR does not require expensive hardware in the way that virtual reality does. All you need is a smartphone and the associated application.

According to Pew Research Center[23], a nonpartisan fact tank, 73 percent of teens have access to a smartphone, which makes the technology readily available.

AR may also enable the user to respond to learning in their own way, and take ownership of the learning experience. They may also react in real time, and make their own choices of the narrative.

In a classroom setting, it may also be more comfortable for students to collaborate on different tasks and be more independent in their learning, which makes it easier for a teacher to focus on helping and making sure everyone is taking part.

You are also able to virtually travel to places you would otherwise not be able to go to. See microorganisms, animals, countries or centuries you that is out of our reach and hard to imagine based on text and a two-dimensional picture.

In a paper by Durrani and Pita [24], they discuss if the integration of augmented reality is worth the effort in education. By examining 38 different papers covering topics such as healthcare, engineering, media and art, culture and history, computer studies, automotive and regulations, science, language, dental, general interactive learning environments, professional educations, they concluded that 92 percent of the studies had shown a positive impact. There were also found none negative impacts related to augmented and virtual reality.

2.3.1 Augmented reality and the gender gap

Based on a study by the Organisation for Economic Co-operation and Development(OECD)[25], boys in school have in recent years started to fall behind in school. The OECD explains how young men are significantly more likely than young women to have low levels of skills and poor academic achievement. They are also more likely to leave school early. Many boys find school out of sync with their own personal interests and preferences, which, as a result, often makes them feel disaffected and not motivated to work in school. Results presented in the report show that across OECD countries, boys are 4 percent more likely than girls to be low-achievers in reading, science, and mathematics.

OECD explain [25] how a sizable number of boys who fail to make the grade in all three core PISA subjects is a major challenge for education systems, and that students who perform poorly are hard to motivate and keep in school because there is very little that teachers, school principals, and parents can build on to promote improvement. This may result in students who are disconnected from and disengaged with school, which may make it easier for these students to build an identity based on rebellion against the school and formal education than to engage and invent the effort needed to break the vicious cycle of low performance and low motivation.

According to the OECD [25], boys are in a nutshell:

1. More likely than girls to play video games
2. More likely than girls to spend time on computers and the internet
3. Less likely than girls to read outside of school for enjoyment
4. Less likely than girls to enjoy activities connected with reading
5. More likely than girls to play chess and program computers
6. Less likely than girls to do homework
7. More likely than girls to have negative attitudes towards school
8. More likely than girls to arrive late for school
9. Less likely than girls to engage in school-related work out of intrinsic motivation

Based on the research of OECD[25], video gaming could have positive effects on learning, since video games can be effective cognitive training tools.

2.3.2 Research questions

The thesis is based on studying pupils and their usage of augmented reality in primary school. This means angling the different research questions to fit into a primary school environment. Rather than trying to measure a performance increase in learning, as this can be hard to measure based on the pupils' previous knowledge of the subject and AR, it may also take much longer time than this thesis can afford. The thesis will then focus on the emotional reactions and feelings that the pupils achieve during testing. Based on a USE questionnaire, the pupils will answer how easy the application is to use, how satisfied they are with it, how easy it is to learn and how useful they find it along with other questions digging a bit deeper.

There are a vast number of questions when it comes to AR, depending on the usage. But for the context or DinosARs and education, the main questions are:

1. How can the use of AR, support the implementation of student-centered learning in primary school?

    1a: Is student-centered learning in primary school too soon?

2. How can AR enhance or increase the learner to content interactions for self-directed learning in primary school?

    2a: Would students be more motivated to study outside of school if they had the ability to use AR?

3. How does AR affect the learner experience in interacting with printed learning material?

    3a: Would students like to combine digital and printed material, or keep them separate?

    3b: Do students see any added value/benefits of using AR combined with printed material /Book/physical material?

    3c: Are students more likely to read books if they are augmented with AR?

4. Can AR help close the gender gap in education, where one gender performs better than the other?

    4a: Can AR help boys be more engaged in classes?

    4b: Can AR be used as a learning tool for both genders?

3 Methods and tools

Before the thesis can be successful, several steps had to be taken. Below as seen in Figure 8, is a research model. The research model shows in a simple manner how to thesis unfolded from start to finish. This makes it easier for both the writer and the reader to have a better understanding of what went into the project.

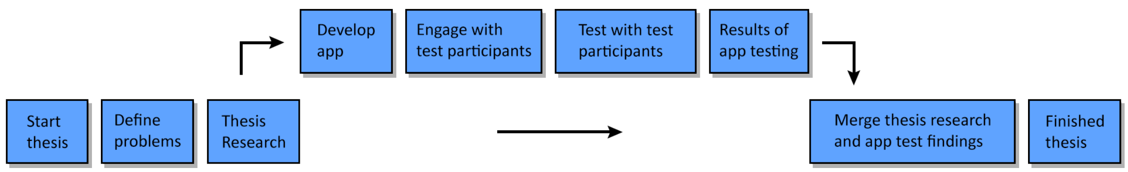


Figure 8: Research model

1. The first step is starting the development of the thesis. This means having a rough idea of what the thesis should contain.

2. The second step is defining the problems. Defining the problems is important to do in an early stage as this may in a lot of cases, define the route that the thesis might take.

3. The third step is doing research in the field of the thesis and finding the main theories and content that the thesis will contain.

4. The fourth step might go in parallel with the thesis research and is developing the application.

5. After completing the development of the application, the fifth step is engaging with test participants and finding people who are willing to test the application.

6. , The sixth step is testing with the test participants.

7. After successfully testing with the participants, the seventh step is gathering the data that was collected during app testing and sorting it, making sense of the data.

8. The second to last step before a finished thesis is taking the research that was made for the thesis and merging it with the information that was gathered during application testing.

3.0.1 Research goals

Augmented reality is not a new technology, but as the technology evolves at rapid rates, it may now be more potent than ever. It is a technology that is now used in a vast range of different areas, ranging from mobile games to hospital surgeries. An area that I find interesting is the use of AR for educational purposes. The goals for this research is to investigate if there is any educational value in bringing this technology into a classroom. This means having to develop an application and test it on real-life subjects in a real environment.

3.0.2 Data gathering during primary school testing

Based on a project by Gjøsæter[18], who tested their AR application, the data gathered from the testing of the DinosARs application in this paper will mostly contain qualitative data gathered with the help of a video, sound, and think-aloud session with the applicants. In the end, there will also be a USE (usefulness, satisfaction, and ease of use) questionnaire.

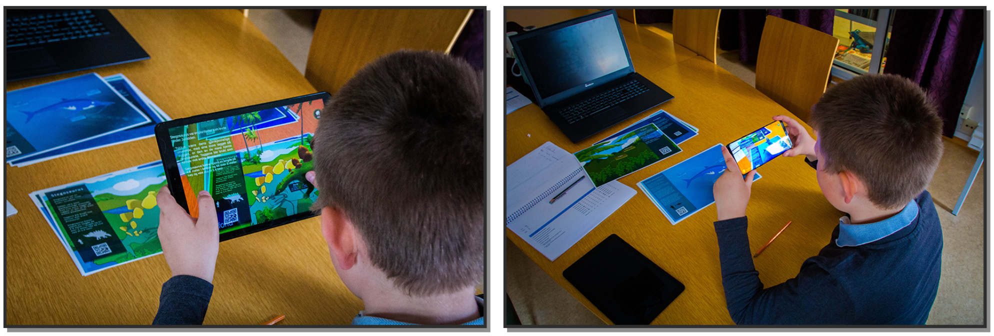


Figure 9: Test participant testing the different devices

3.0.3 Think-aloud technique

The project by Gjøsæter [18] also explains how think-aloud sessions have a strong history in human-computer interaction, and was initially developed and used by Ericcson and Simon in 1980. The technique asks the test subject to think out loud what they are thinking, feeling, and doing. As explained by Gjøsæter[18], this technique can allow the investigations and test user to go beyond the scope of predefined tasks and potential usability pitfalls. After the testing is completed, using the think-aloud method in unison with sound and video recording makes it easier to analyze data that was gathered in the session in retrospect.

3.0.4 Video recording

According to Gjøsæter [18], the use of video-based qualitative research has, in recent years, gained increasing popularity in fields such as computer-supported collaborative work and human-computer interaction. He also explains how the key advantage of the method is that it can help capture aspects of social activities in real-time, such as talk, visible conduct, and the use of tools, technologies, objects, and artifacts.

3.0.5 Recording setup

Before recording any of the users, an application to the NSD (Norsk Senter for Forskningsdata, The Norwegian Centre for Research Data) had to be made.

This is to make sure that the users know their rights during testing. It is also done to make sure that the test participants know what kind of research is going to be done. The researcher himself also makes sure that everyone knows what they are up to and does not do anything illegal. So before any testing was done, the user's legal guardian had to sign a paper that accepted their participation and that they could at any time ask for the deletion of footage or withdraw from the research.

For the setup itself, the cameras will be placed in fixed positions, to keep the interaction with the application as natural and fluid as possible, as a handheld recording might interrupt the user from their tasks.

3.0.6 Quantitative data

The study will collect quantitative data in the form of a USE questionnaire. Here the user will have the option to answer statements using a 7 point Likert scale, scaling from "Strongly agree" to "Strongly disagree." The questionnaires will consist of an introduction, where the student answers questions about previous knowledge of AR, smart devices, the use of digital learning materials, their interest in dinosaurs and if they want to use smart devices for learning. After the introduction and testing of the application, the student will go through a USE questionnaire, answering how useful, easy to use and how easy to learn the application and technology was and how satisfied they were with it.

3.1 Interaction design and field testing

Interaction design is the design behind the use of interfaces between people and computers. For the user to end up with a product that is easy to use, has good user experience, and looks good; human-computer interaction is needed. This section will explain some of the things that have to be considered about HCI when designing AR applications.

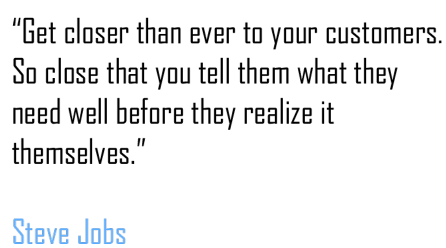


Figure 10: Quote By Steve Jobs

According to a study from 2014[26], there are fundamental differences between traditional GUI systems and AR systems. The study also explains how a normal GUI is usually designed to be used with a mouse, keyboard, and a screen. Usually, this is done in 2D. In an augmented reality setting, on the other hand, you tend to use a touch device like a smartphone or head-mounted goggles like the Microsoft Hololens. This is also something that is usually happening in 3D. The study also explains how this is something that has to be taken into consideration, as traditional HCI methods can be used to determine what information should be presented, but they do not show **how** to present the information.

According to the same study [26], there are a few design principles you should think of when developing an AR application:

- **Affordance** to make the application have an inherent connection between a user interface and its functions. This can be achieved by providing a model describing subject-object relationships.
- **Reducing cognitive overhead** to allow the focus on the actual task instead of overwhelming the user with information resulting in poor user experience.
- **Low physical effort** to make a task accomplishable with a minimum of interaction steps. Applications with interaction that is too complex will not be successful.
- **Learnability** to provide easy learnability for a user. As AR provides novel interaction techniques, the usage of those techniques have to be easy to learn.
- **Error tolerance** to deliver stable applications. As AR systems are mostly in early development stages, there exist many bugs. Applications should be able to continue working even when experiencing an error.

These were all steps that were taken into consideration when developing the application.

3.1.1 Measuring performance

Measuring the performance of AR might sometimes pose a challenge. What do you measure? Having a simple quiz and a point system to see if you've learned the subject might not cover all measurable areas. According to [26], four categories should be evaluated:

- **Task Performance** to evaluate user accomplishments when using the system
- **Perception and Cognition** to understand how perception and cognition work in AR
- **Collaboration** to evaluate the interaction of multiple users.
- **User experience** to evaluate the user's subjective feelings

3.1.2 Designing for user experience

To more easily understand the different aspects of user experience when developing the application, and in this case, also test it, Peter Morvilles user experience honeycomb [6] will be of inspiration. Peter Morville is a designer and information architect who has experience in the field since 1994 and designed the honeycomb to more easily explain that there are many different aspects outside of usability.

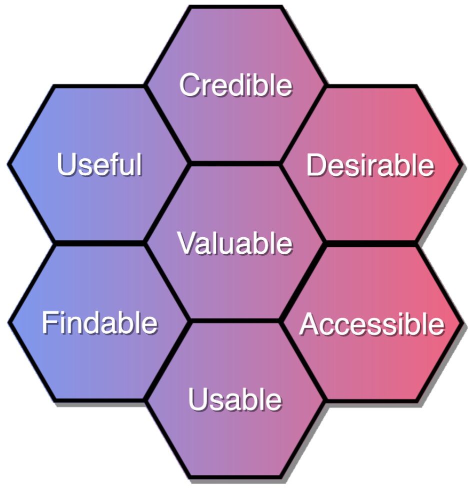


Figure 11: Peter Morville's honeycomb [6]

According to Morville[6], there are seven different user experience aspects of the honeycomb. These are;

1. **Useable** The system in which the product or service is delivered needs to be simple and easy to use. Systems should be designed in a way that is familiar and easy to understand. The learning curve a user must go through should be as short and painless as possible.

2. **Useful** A business's product or service needs to be useful and fill a need. If the product or service is not useful or fulfilling user's wants or needs, then there is no real purpose for the product itself.

3. **Desirable** The visual aesthetics of the product, service, or system need to be attractive and easy to translate. The design should be minimal and to the point.

4. **Findable** Information needs to be findable and easy to navigate. If the user has a problem, they should be able to find a solution quickly. The navigational structure should also be set up in a way that makes sense.

5. **Accessible** The product or services should be designed so that even users with disabilities can have the same user experience as others.

6. **Credible** The company and its products or services need to be trustworthy.

Morville explains [6] how by looking at the honeycomb, stakeholders can identify the most important areas, and from the start om the project, begin working on the high-level priorities.

When testing the DinosARs application, going through each of the categories with the users will help polish the product. It will also see where it needs to be improved and where it succeeds.

3.2 Context of use

A human-centered design approach was used throughout the entire project period. This approach involved a large focus on understanding the context of use and understanding who the intended users are, and what tasks they perform. It was important to try to see things from the users perspective. It is essential to understand who the intended users are and what tasks they are supposed to perform. It is also important to understand the environment om which they are going to use the application and where it will fit in the system they already have.

3.2.1 Planning phase

Before starting the project, finding out who the application is intended for is paramount. It was decided that it should aim at a younger audience, in this case, ages 8 to 14. The application to be easy to use and understand, but also fun and interactive. After completing the application, one of the paramount aspects of the thesis was user-testing.

3.2.2 Environment of the system

Understanding the organizational environment is a vital part because this is the environment the product is going to fit in to. In this case, the application is aimed at students, as a learning tool, and will, therefore, most likely be used in a classroom setting. This means having a light setting that might not be optimal for the camera and therefore, the application. Not having an optimal light setting, might make the room too dark, or even too bright, ending up displaying a glare on the paper through the camera.

3.2.3 Defining requirements

To define the requirements of the application, the guidelines of the Volere requirement specification template are as followed. There are two types of requirements: functional and non-functional. Below is an example of how some of the functional requirements were specified.

Requirements #: 1

Requirement Type: Functional

Description: The application shall allow the user to interact and learn about dinosaurs with the help of AR

Rationale: Students have different ways of learning, and AR might have the ability to reach out to more students

Source: Knut-Erik Krogstad Aastveit

Fit Criterion: By merging the real and virtual world, displaying 3D images in real time with the added affect of sound and interaction, the user can view object that would otherwise be hard to visualize on paper or in two dimension

Customer Dissatisfaction: 5

Customer Satisfaction: 5

Priority: High

Figure 12: Requirement 1 - The first requirement is that the application shall allow the user to interact and learn about dinosaurs with the help of AR. This is paramount for the application to have any effect.

The non-functional requirements were divided into four groups. Below is a list of each group with a few examples of the requirements specified in them:

1. Look and feel requirements
   - The device should be lightweight, and easy to transport.
2. Usability and humanity requirements
   - The application should be easy to use.
   - The application should be easy to learn, without too many settings or features.
   - Icons and buttons should be easy to understand
   - Icons and buttons should be easy to see
3. Performance requirements
   - The device should have sufficient enough hardware to run an augmented reality. For iOS devices that means iPhone 6s and later, and iPad 2017 and later. For Android, recommended specs are 4GB RAM and a 1.5 GHz processor.
   - The application should have low tolerance error when it comes to recognizing the identification markers in the book.
   - The device should have a good enough camera so that the markers are identifiable.
   - The device that is running the application should have a display of at least 5 inches for better user experience. This will make it easier to view the models and interact with them.

- The application should not crash or spent too much time loading.

4. Operational and environmental requirements
    - The product should be usable in dim light.
    - The product should be usable in crowded environments.
    - The product should be usable in rooms with bright lights.

3.2.4 Identifying organizational and physical environment

Understanding the organizational environment is a vital part because this is the environment the product is going be used in. In this case, the product is an application that teaches the user about dinosaurs with the help of a device and real pictures that projects AR models, sound and interaction onto the paper. It is therefore important for the user to have enough room to move around the images, and also a flat surface to place the pages on. It will most likely be used on a table in a classroom, kitchen, or living room. It is also vital that the room has good enough lighting so that the camera is able to view the page, but also not glare the picture, which can make it difficult for the camera to recognize the images. Therefore the image has to be printed on the correct type of paper for optimal performance.

3.2.5 Users of the system

There are mainly two groups of users that will use the application. The student and the teacher. The teacher should have the knowledge to show the students how the application works and in cases where there are issues, the teacher should be able to help the student solve it.

The other user, the student, is the primary user. This application may be used by a single person or in groups. They might not be as technical as the teacher, or they might not be able to handle equipment in the same fine-tuned way.

3.2.6 Identifying the user

When developing an application, having a clear idea of who the target user is, is important. In this case, the aimed user is children between 8 and 14. To get a glimpse of how the mind of someone between 8 and 14 works, creating a persona can help. The persona is a fictional character made to represent the intended user. This includes their skills, abilities interest, experience and so on.

Name: Aria Nettod
Age: 10
Sex: Girl
Occupation: Student at a good primary school
Language: Norwegian

Aria is an active, outgoing 11-year-old girl attending primary school. For her age, she is intelligent and is usually ahead of schedule, which sometimes makes attending classes a drag as there is no challenge. Her teacher has given her a few extra tasks that she can do, but they are usually completed soon after. In her spare time, she likes to hang out with friends, play Fortnite, and ride her horse. When she grows up, she wants to be either a veterinarian or a Twitch streamer.

3.2.7 User stories

- As a class teacher, I want to be able to have more time for my students. This can be achieved by letting them work in groups or with devices that let them be more independent.
- As a class teacher, I want the students to take ownership of their learning and be more in charge.
- As a class teacher, I want to embrace new technology, that might engage more students.
- As a student, I want to have fun with my friends, and be able to group up and solve tasks together.
- As a student, I sometimes find it hard to envision complex drawing or words.

3.2.8 Scenario

Class 3B has a history class. Today they are learning about dinosaurs. Dinosaurs are creatures that lived millions of years ago, and usually, the class has to read about them in books, or, on some occasions, watch them in movies. But today is different. Their teacher Ralf has brought with him a few tablets, with the application DinosARs on them. With this application, the class can get to know dinosaurs in a different way, compared to what they are used to. Ralf divides the students into groups, as there are just a set amount of tablets. They are also given a copy of the DinosARs book, that contains all the pages that the students will interact with. Now divided into groups, the students sit down and start the application. They are now able to hover their tablet over the pages and view the different species of dinosaurs in all their glory. They can interact, watch them move around, hear them roar, and read facts about them.

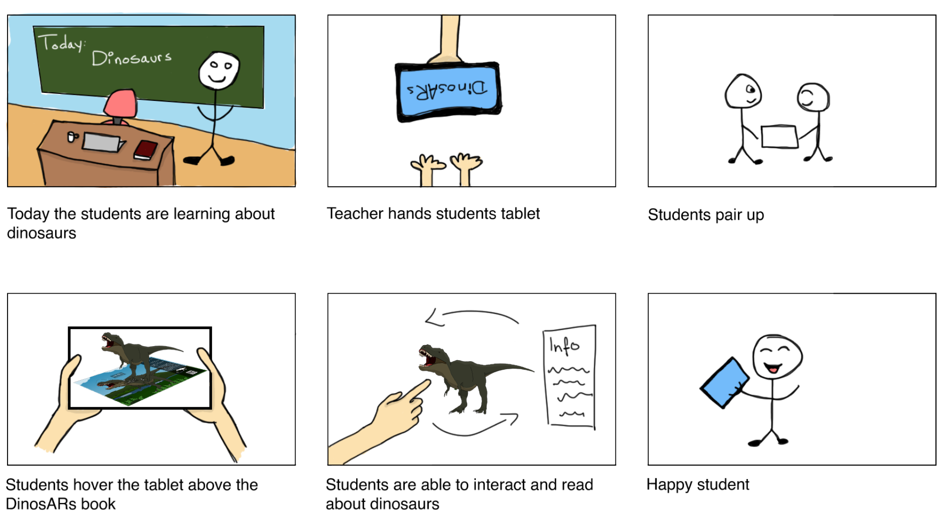


Figure 13: Storyboard

3.3 Tools and development

Throughout the project, several steps had to be done before a satisfying result was achieved. There were in total two iterations, one before the start of the thesis, and one during. When creating the application, several tools were utilized. These were based on previous knowledge and ease of use. The goal was to create a product that could be completed in the available time frame, and at the same time be a pleasing product to use.

The tools used were:

1. Unity as the game engine
2. Vuforia for AR development
3. Visual Studio for C Sharp coding
4. 3D Studio Max for 3D modeling and development
5. Substance Painter for texture development

Hardware tools were also used. In this case, the application has been developed for the Samsung s8+ when that is the phone that I am using. Augmented Reality can be tough on some phones, as it requires a certain amount of hardware performance. Vuforia recommends a Samsung S6 or higher, with at least Android 4.1.

The application was later in the process further developed to suit the 2018 Samsung Galaxy Tab A as this is the second handheld device that the students will interact with.

The Microsoft Hololens was also a test subject that was interesting and I spent some time on. Due to many bugs within Unity, Visual Studio and the Hololens itself, the Hololens as a hardware tool was discarded as developing an application for it from scratch would take too long. On the other hand, it definitely has potential, and could be a future research topic, as using AR on a headset compared to a mobile device is, in my opinion, two very different experiences.

3.3.1 Conceptual model of how to navigate and use the application

I wanted the layout of the application to be pretty basic and intuitive. There are few buttons, which should make it easy for all kinds of users to understand how to navigate the application. When you start the DinosARs, you are loaded into the main menu, which gives you two options. The start button that starts the AR mode, and an instruction button, that gives you a simple explanation of the application and how to use it. If you choose to start the AR mode, you are then able to interact with the augmented book pages. You can also toggle the information boxes on and off. Turning them off will make it easier for the user to view the 3D models without any text. You can also toggle the information boxes back on if you want to read about the content on the page.

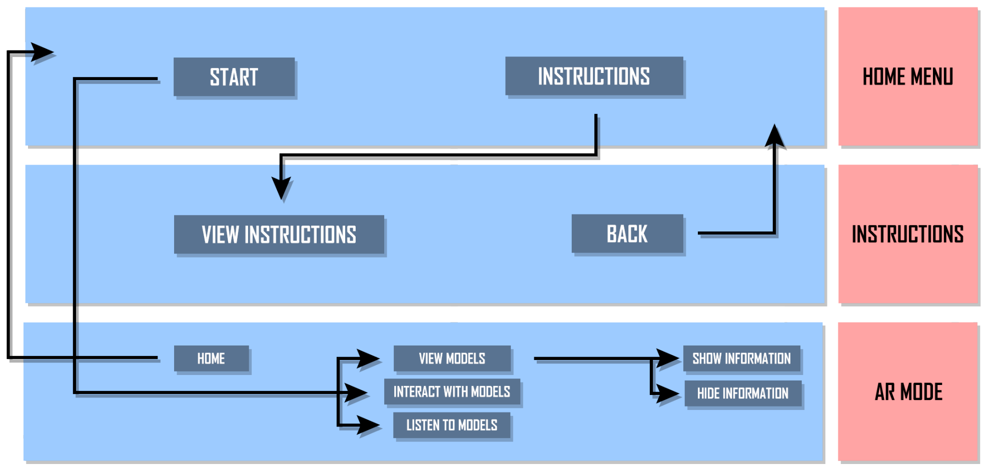


Figure 14: Concept model of the application

As mentioned in the report of Robinson, Arbez, Birta, Tolk, and Wagner [27] about the definition, purpose, and benefits of conceptual modeling, Robinson perspective of a conceptual model is that it provides a means of communication between all parties. An example can be the communication between a modeler, a code developer, domain experts, end users, and clients. The report also explains the benefits of a documented conceptual model.

- It minimizes the likelihood of incomplete, unclear, inconsistent and wrong requirements
- It helps build the credibility of the model
- It guides the development of the computer model
- It forms the basis for model verification and guides model validation
- It guides experimentation by expressing the modeling objectives, and model inputs and outputs
- It provides the basis of the model documentation
- It can act as an aid to independent verification and validation when it is required
- It helps determine the appropriateness of the model or its parts for model reuse and distributed simulation

He concludes that the conceptual model exists in the mind of the modeler. The documentation and model code are means for making that model explicit.

3.3.2 First iteration

The application was developed as a prototype in the course MM - 503 - Project. When first starting the project, I knew this was what wanted to base my master thesis on. Having already learned the basics of AR development in MM - 503 would make it easier to focus on testing and polishing. The first iteration was more of an experiment to see what the technology has in store, and what I was able to do it with.

As mentioned above, the development of DinosARs started in the second semester of 2018 in the MM - 503 - Project course. The project idea was developed to create a challenge for myself, as I had never developed anything in AR and at the point had little experience with Unity. AR is also a technology that I see myself working within the future, as I find it fun, interesting, and with great potential. The focus at this point was to do thorough research into AR, before starting on the development of the application. The result was that there was a limited time to polish the final product as it had to be delivered at the end of the semester.

The project is using a software called Vuforia. Vuforia is a software development kit (SDK) that is available in Unity and allows the user to develop AR applications inside Unity. Vuforia can recognize different shapes and place digital models on top of it. Vuforia was chosen over competitors like ARKit and ARCore due to being native to Unity and its ability to easily track ID markers without too much work and coding. To be able to do this, you have to upload either an image, cube, cylinder, or a 3D object into the Vuforia database.

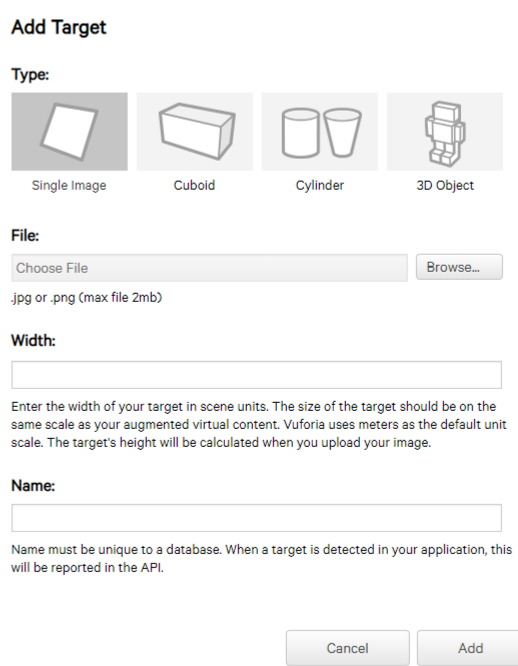


Figure 15: Database target types

After uploading something into the database, it is then rated from 1-5 stars, based on how easy it is for the software to recognize the target as an AR image. It is important to achieve as many starts as possible, as this may significantly improve the user experience, as the software will feel more fluid and be able to keep track of the images in an easy way.

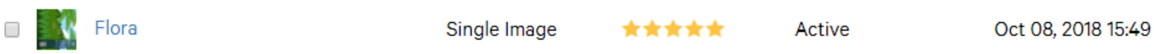


Figure 16: Vuforia rating system

The technique used for the development of DinosARs is the recognition of ID markers. This means that the software needs an identifiable image that it can project its 3D models on top of. Adobe Photoshop was used to create the markers. I wanted a homemade, cartoony style that would seem fun and inviting to the younger audience. To achieve this kind of style, all the pages had to be drawn by hand.

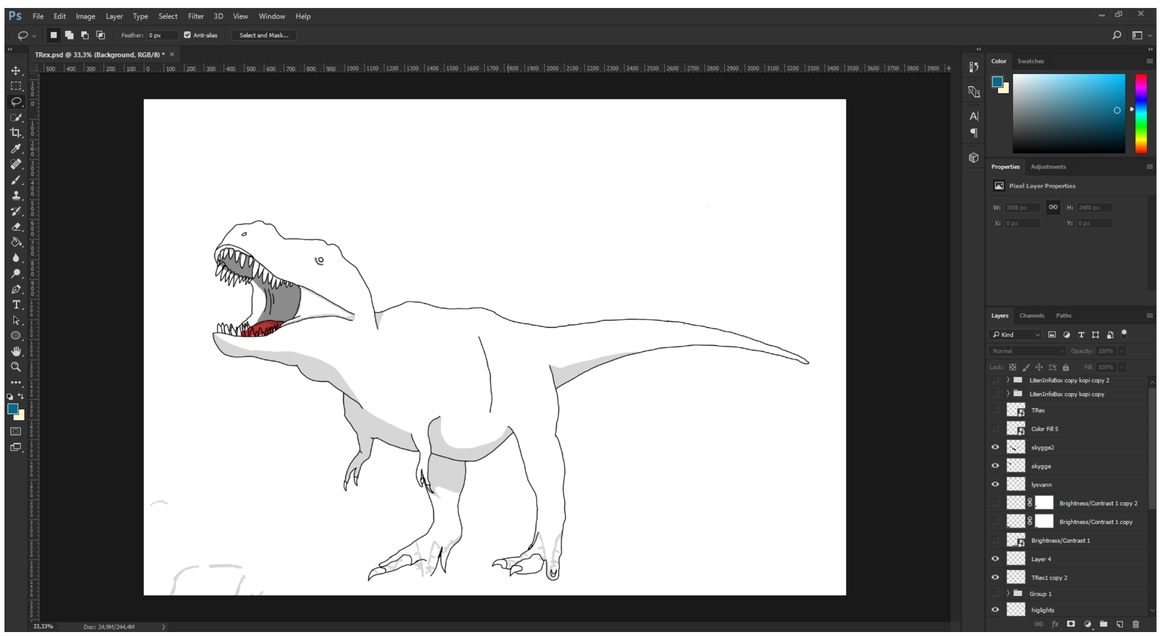


Figure 17: Photoshop

To make sure that the images are easy to track, especially since the application is targeting a younger audience, that might not have motor skills as acute as an adult user; every image has also a QR code. Having a QR code is not something that Vurforia requires, but the QR codes make it easier for Vuforia to keep track of the page, making sure that whoever uses it will always be able to track the pages.

After drawing a dinosaur in Photoshop, models were downloaded from www.Turbosquid.com and the Unity Store to save time and achieve a satisfying result. They were then loaded into 3D Studio Max (3DS) for rigging and skinning, before being transferred to Substance Painter. 3DS was used, as most of the files from Turbosquid are supported by 3DS. It is also a program I had previous knowledge of, which made it easier to work with.

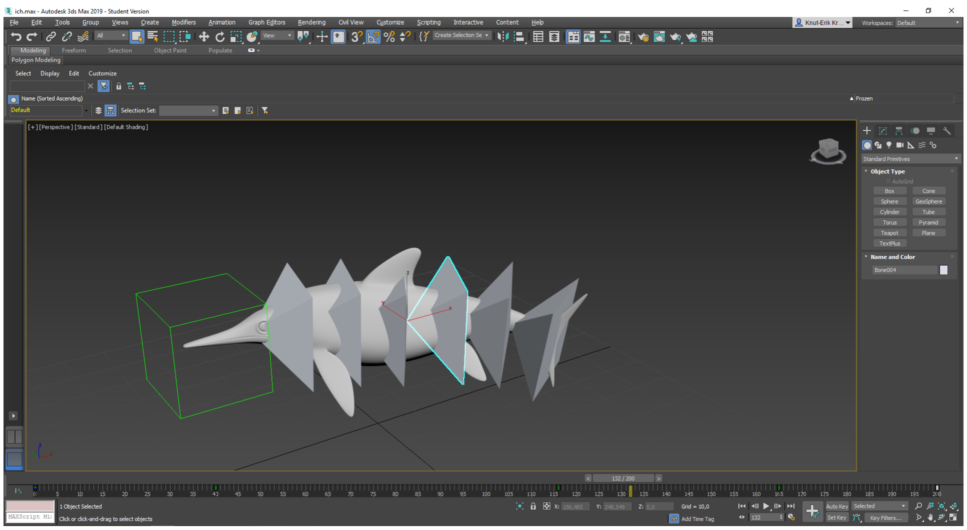


Figure 18: 3D Studio Max

Substance Painter is a program that allows the user to create textures based on UV maps that were created in 3DS. Using Substance Painter gave the dinosaurs a much more realistic look. In Substance Painter, the models were drawn and colored to mirror the drawings as much as possible. Some dinosaurs were also given features like scars and muddy skin to try to reenact what might've happened in real life.

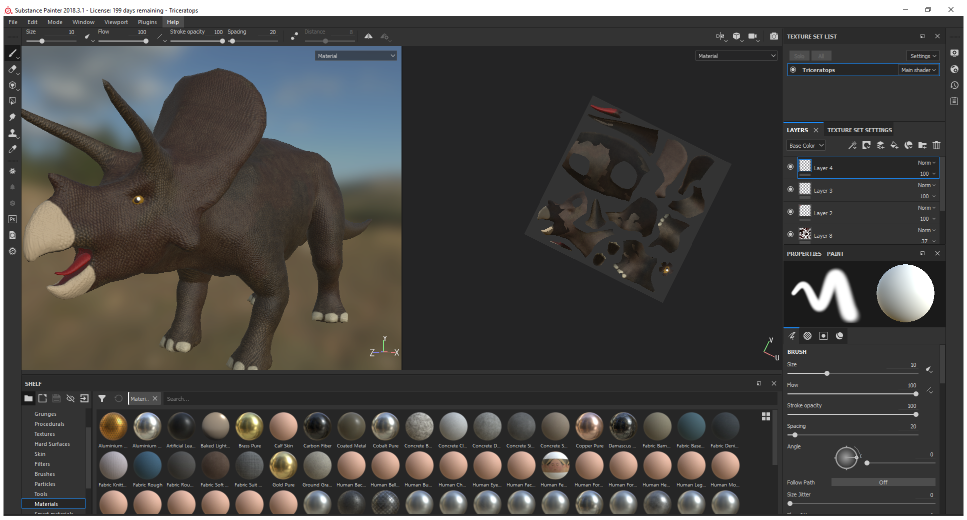


Figure 19: Substance Painter

Without too much prior knowledge of C Sharp, this was a language that required a lot of research before starting the project. Fortunately, the Unity community is a large one, and there is a lot of help to be received. Unity also has an asset store, where you can download assets to your project. An example is the LeanTouch asset which was downloaded and used in the application. LeanTouch is an asset that makes the user able to interact with the application and its Game Objects using touch.

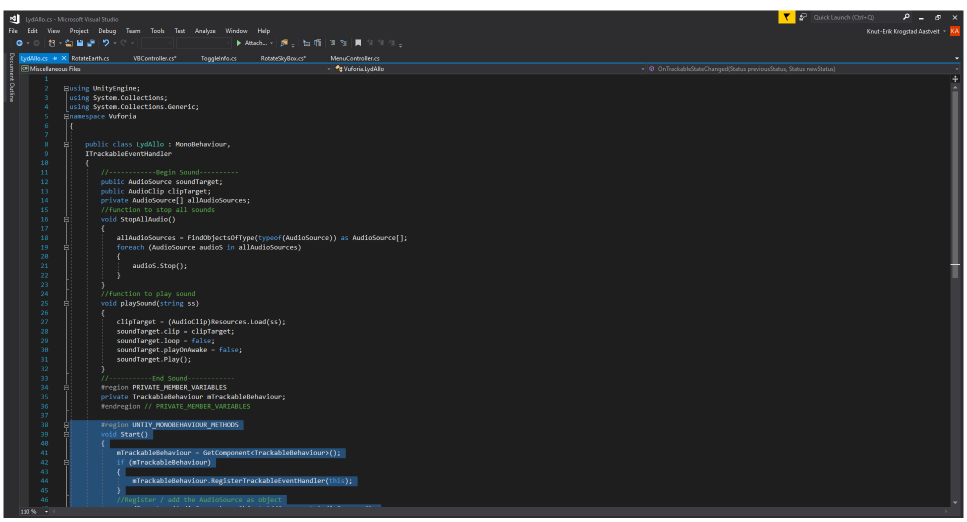


Figure 20: Visual Studio

There was also conducted a lot of research on AR button. An AR button is a button that is placed as a digital element in the real world, in this case, on the different DinosARs pages. For you to interact with this button, means that you have to press it where it is placed on the page, not on your handheld device. This type of button allows you to interact with the physical material, rather than a digital representation of a button on your device. As a result, the button will stay in the same place on relative to the object that it is placed on, rather than staying static on the device. Buttons of this kind were found cool and fun when they worked, but too often they did not work as intended. The user would sometimes have to press the same button several times in a specific angle before it worked. An AR button also lacks haptic feedback, making the experience less pleasing. When a user presses a button, the user should expect an immediate reaction, having to press the button several times without a response is not good interaction design. Therefore, it was decided to remove the AR buttons, and have fully functioning static buttons instead.

After a model has been rigged and UV mapped in 3DS, textures created in Substance Painter and pages drawn in Photoshop, the finished results can be loaded into Unity and the Vuforia Database. Here everything is assembled into a final result. Pages are laid out, and models, sound, and text are added.

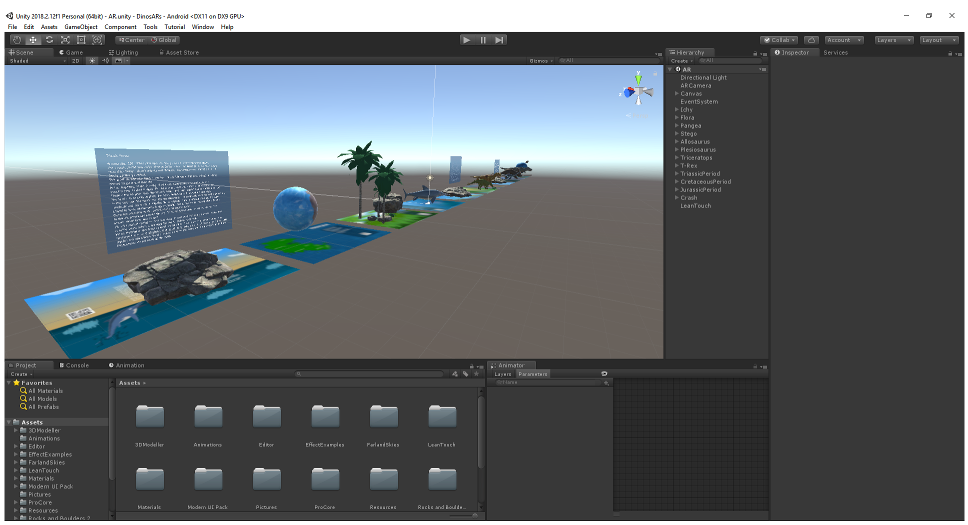


Figure 21: Unity

3.3.3 Second iteration

The second iteration of the application was done while developing the master thesis. This time, the application was going to be tested in a real-life situation on students. The application, therefore, had to be polished and tested to make sure that it ran on the 2018 Samsung Tab A tablets that were going to be used.

As the pages had in the old prototype had been pretty empty, they needed to be filled with models that fit the dinosaur being displayed. This was done to make each page seem more true to its nature, more inviting, and have more content on it. the result was pages that looked more complete and realistic to the user.

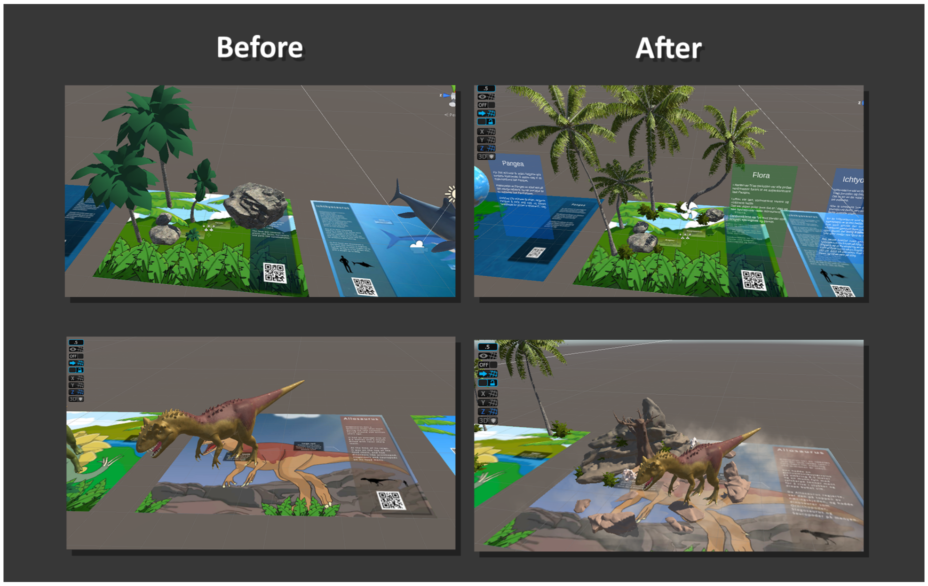


Figure 22: Example of a couple of upgraded pages

When arriving at the home menu, the leaves, ferns, logo, and palms are now also animated to make things more alive and fluent. For the images to work on the Samsung Tab A 10.5, the images had to be reworked and scaled to fit its native resolution.

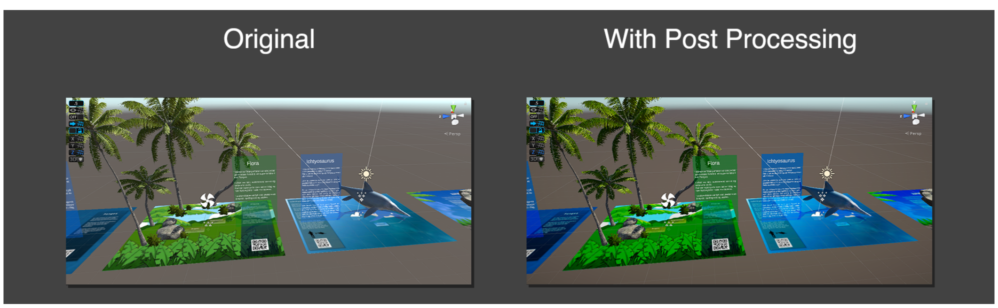


Figure 23: Post Processing

A post-processing behavior was also included, which makes the user able to adjust features like color grading, anti-aliasing, bloom, and so on. This makes colors, details, and environment look more alive and the images seem to pop out compared to earlier versions. But due to the limited hardware resources of the Samsung Tab A 10.5, features like ambient occlusion, bloom and anti-aliasing could not be implemented. These are things that make images pop out even more, but require a lot more computer power. Therefore, color grading is the only feature for the tablet that was included. Any other features than color grading made the tablet run too slow for it to be satisfying, so to make sure that the application runs as smooth as possible, only color grading was added.

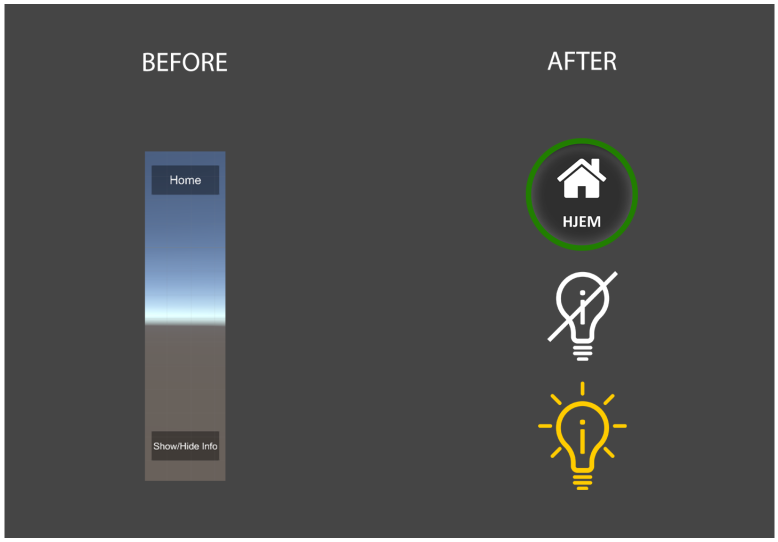


Figure 24: New navigation buttons

For the younger audience to more easily navigate within the application, the buttons for going back to the home menu and hiding and showing the information boxes were changed to something a bit more intuitive. This means having a button that more clearly defines what it does with the help of graphics. The old design as seen on the left of figure 24, is very basic, and for people who can't read, it might not be self-evident what they mean. On the right side of figure 24, you can see the new design. These days, most people recognize the house icon as a home button, which may make it easier for the user to understand what it does. The new information toggle button also received a new design with a light-bulb with an i inside the bulb to illustrate that it turns the information boxes on and off, depending on if the user wants to display the information text on the pages or not.

A couple of new pages was also created. A front page that can be seen below, and an introduction to the AR book, that gives a simple explanation about what it is.

Figure 25: New front page

First and foremost, all text was translated from English to Norwegian. This was important as the users are going to be mostly Norwegian children.

The new text is made with a Unity Asset called TextMeshPro. TextMeshPro is an asset that makes it easier to change the visuals of a text dynamically. It also scales better, which makes it easier to view the text through different devices. The previous text was made in 3DS, which didn't scale very well and is not as easy to work with in Unity as TextMeshPro.

Several pages also received a particle system or a wind system. This is to make things more lifelike and immersive. Having trees blowing in the wind or bubbles rising from the ocean might make things more believable and crisp. One could think of particle systems as the salt and pepper of game development.

To more easily understand the application, we will go through the different steps of the app. We start the application by launching it through the application icon, as seen in figure 26.

Figure 26: Application icon

After opening the application. The user will meet the main menu that gives you two choices. Start the augmented reality aspect of the application, or read the instructions.

Figure 27: Main menu

If you choose to read the instructions, the background will change to a more red color, and the application will greet you with a message that gives a small explanation of how to use the application.

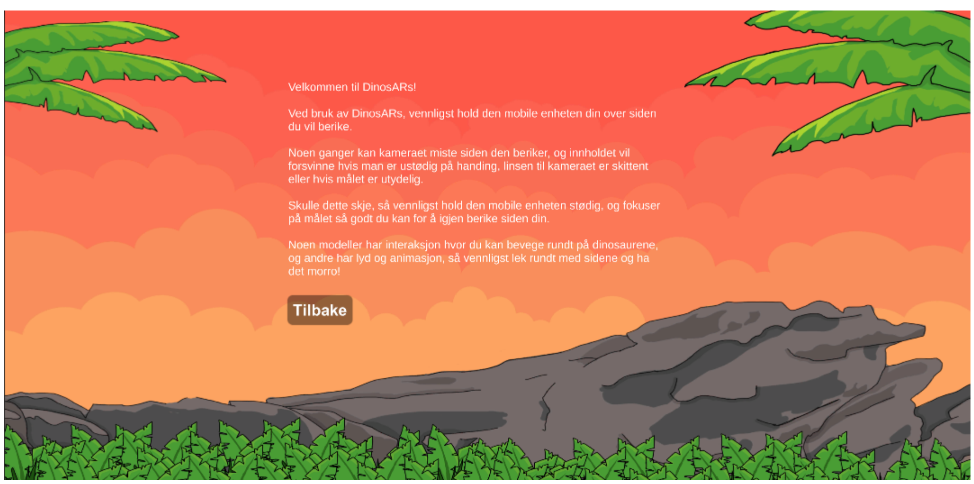


Figure 28: Instructions

When launching the augmented reality part of the app, you will have to place one of the pages from the pamphlet in front of the camera. When doing so, a 3D model will appear on top of the page. Each page also has a sound that will start playing, depending on the page, and will stop playing when the page is removed. Most of the models are also interactable in the form of being able to zoom or rotate the model. Some of them are also animated and will move around.

Each page also has an information box that is at default toggled off. In the bottom right corner, there is a button that will allow you to toggle the box on or off, making you able to read the text in augmented reality. If you want to go back to the main menu, you can press the home button, and it will take you there.

Figure 29: AR

4 Testing of the application and AR technology

The testing of the application takes place on Blakstadheia primary school in Froland, Norway. Here, pupils from third and fourth grade will test the application, where the pupils' age range from 8-10 years old. There were in total 10 students, where three girls and two boys attended third grade and three boys and two girls attended fourth grade.

4.1 Userbased testing plan

As Abraham Lincoln might have once said; "Give me six hours to chop down a tree, and I will spend the first four sharpening the ax." Being prepared and having a plan when testing is crucial. Below in figure 30, is the basic outline of what the first test will look like.

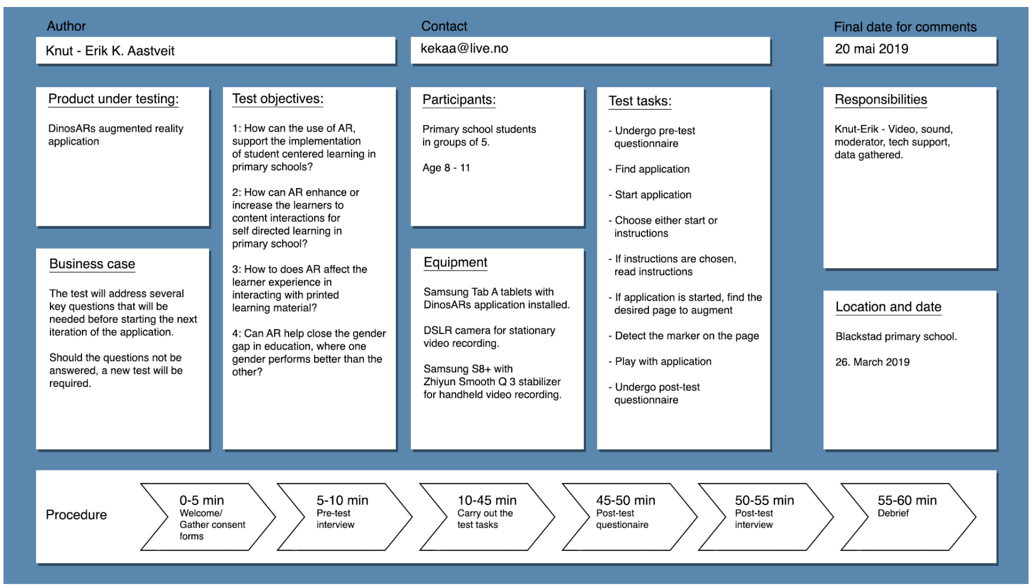


Figure 30: Usability test plan based on Dr. David Travis design [7]

4.2 Pre and post-test interviews

Both before testing and after, the pupils had to go through a pre-test interview and a post-test interview, which also came with a questionnaire. As seen on the next page in figure 31, 32, 33, and 34, you can see the different questions they had to answer before and after testing.

Questionnaire

Boy ○

Girl ○

Age: ______

Introduksjon		1	2	3	4	5	6	7		NA
1: I know what augmented reality is	Strongly disagree	○	○	○	○	○	○	○	Strongly agree	○
2: I have heard about augmented reality before	Strongly disagree	○	○	○	○	○	○	○	Strongly agree	○
3: I have used augmented reality before	Strongly disagree	○	○	○	○	○	○	○	Strongly agree	○
4: I sometimes use augmented reality to learn	Strongly disagree	○	○	○	○	○	○	○	Strongly agree	○
5: I have a smartphone	Strongly disagree	○	○	○	○	○	○	○	Strongly agree	○
6: I like dinosaurs	Strongly disagree	○	○	○	○	○	○	○	Strongly agree	○
7: I have used a smartphone of a tablet at school or home to learn	Strongly disagree	○	○	○	○	○	○	○	Strongly agree	○
8: I want to use a smartphone of a tablet at school or home to learn	Strongly disagree	○	○	○	○	○	○	○	Strongly agree	○

Figure 31: Pre-test questionnaire

Before testing, the pupils were handed a questionnaire where they had to answer basic questions about their previous experience with AR, their experience with applications and smart devices, and finally their gender and age. After completing the first pre-test questionnaire, the pupils were allowed to pick either the tablet or smartphone, depending on their preference, and start the application.

Questionnaire

Usefulness		1	2	3	4	5	6	7		NA
1: DinosARs helps me to be more effective	Strongly disagree	○	○	○	○	○	○	○	Strongly agree	○
2: DinosARs helps me to be more productive	Strongly disagree	○	○	○	○	○	○	○	Strongly agree	○
3: DinosARs is useful	Strongly disagree	○	○	○	○	○	○	○	Strongly agree	○
4: DinosARs makes it easier for me to get things like homework done	Strongly disagree	○	○	○	○	○	○	○	Strongly agree	○
5: DinosARs saves me time	Strongly disagree	○	○	○	○	○	○	○	Strongly agree	○

Ease of use		1	2	3	4	5	6	7		NA
1: DinosARs is easy to use	Strongly disagree	○	○	○	○	○	○	○	Strongly agree	○
2: DinosARs is user friendly	Strongly disagree	○	○	○	○	○	○	○	Strongly agree	○
3: DinosARs uses few steps to do what I want	Strongly disagree	○	○	○	○	○	○	○	Strongly agree	○
4: I manage to use DinosARs successfully every time	Strongly disagree	○	○	○	○	○	○	○	Strongly agree	○
5: I manage to use DinosARs without instructions	Strongly disagree	○	○	○	○	○	○	○	Strongly agree	○
6: If an error occurs, I can easily fix it	Strongly disagree	○	○	○	○	○	○	○	Strongly agree	○

Figure 32: Usefulness and Ease of Use

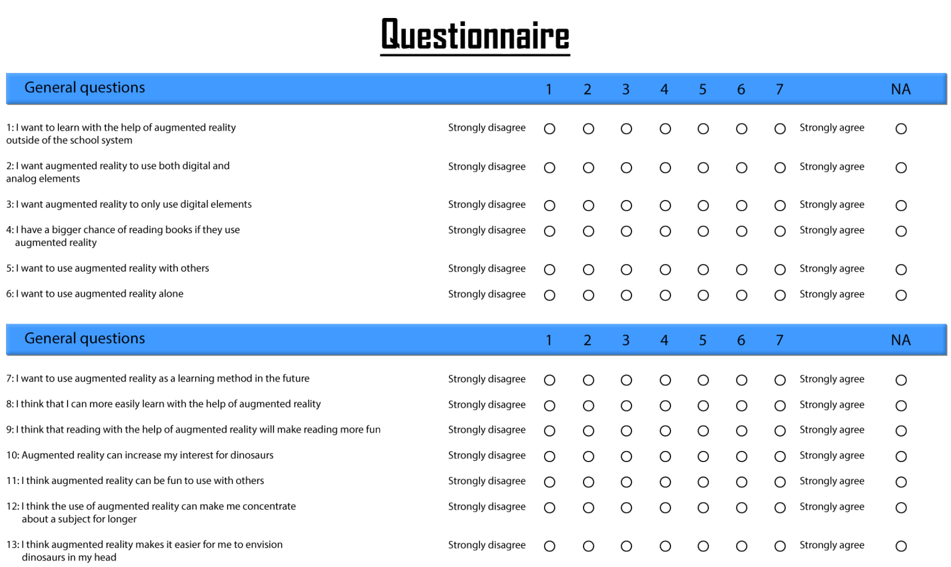
Spørreskjema

Enkel å lære		1	2	3	4	5	6	7		NA
1: I learned to use DinosARs quickly	Strongly agree	○	○	○	○	○	○	○	Strongly disagree	○
2: I can easily remember how to use DinosARs	Strongly agree	○	○	○	○	○	○	○	Strongly disagree	○
3: It is easy to learn how to use DinosARs	Strongly agree	○	○	○	○	○	○	○	Strongly disagree	○
4: I quickly got good at it	Strongly agree	○	○	○	○	○	○	○	Strongly disagree	○

Tilfredshet		1	2	3	4	5	6	7		NA
1: I am satisfied with the application	Strongly agree	○	○	○	○	○	○	○	Strongly disagree	○
2: I would recommend DinosARs to a friend	Strongly agree	○	○	○	○	○	○	○	Strongly disagree	○
3: DinosARs is fun to use	Strongly agree	○	○	○	○	○	○	○	Strongly disagree	○
4: DinosARs does everything I expect it to do	Strongly agree	○	○	○	○	○	○	○	Strongly disagree	○

Figure 33: Ease of Learning and Satisfaction.

After going through all the different pages, utilizing the think-aloud method, where the pupils say whatever pops up in their head at the time, the pupils were given the post-test questionnaire. This post-test questionnaire is based on a USE questionnaire [28], where the pupils had to answer questions about usefulness, ease of use, ease of learning, and satisfaction.



Questionnaire

General questions		1	2	3	4	5	6	7		NA
1: I want to learn with the help of augmented reality outside of the school system	Strongly disagree	○	○	○	○	○	○	○	Strongly agree	○
2: I want augmented reality to use both digital and analog elements	Strongly disagree	○	○	○	○	○	○	○	Strongly agree	○
3: I want augmented reality to only use digital elements	Strongly disagree	○	○	○	○	○	○	○	Strongly agree	○
4: I have a bigger chance of reading books if they use augmented reality	Strongly disagree	○	○	○	○	○	○	○	Strongly agree	○
5: I want to use augmented reality with others	Strongly disagree	○	○	○	○	○	○	○	Strongly agree	○
6: I want to use augmented reality alone	Strongly disagree	○	○	○	○	○	○	○	Strongly agree	○

General questions		1	2	3	4	5	6	7		NA
7: I want to use augmented reality as a learning method in the future	Strongly disagree	○	○	○	○	○	○	○	Strongly agree	○
8: I think that I can more easily learn with the help of augmented reality	Strongly disagree	○	○	○	○	○	○	○	Strongly agree	○
9: I think that reading with the help of augmented reality will make reading more fun	Strongly disagree	○	○	○	○	○	○	○	Strongly agree	○
10: Augmented reality can increase my interest for dinosaurs	Strongly disagree	○	○	○	○	○	○	○	Strongly agree	○
11: I think augmented reality can be fun to use with others	Strongly disagree	○	○	○	○	○	○	○	Strongly agree	○
12: I think the use of augmented reality can make me concentrate about a subject for longer	Strongly disagree	○	○	○	○	○	○	○	Strongly agree	○
13: I think augmented reality makes it easier for me to envision dinosaurs in my head	Strongly disagree	○	○	○	○	○	○	○	Strongly agree	○

Figure 34: General questions about the pupils attitude towards AR and the application post-test

The pupils were also assigned a last questionnaire with general questions about augmented reality and what they thought about the technology and what the pupils could do with AR and what AR could do for them.

4.3 Testing with participants at Blakstadheia primary school

The testing did as mentioned take place in Blakstadheia primary school in Froland, Norway. It was held in two controlled environments, where no one could interrupt the pupils while testing. This was important as the school, in general, was very busy, with a lot of young children running around in the halls screaming, which could interfere with the testing of the application. The testing itself went over three days.

The first day of testing was scheduled to test five pupils. But due to time limitations at the school, it was only possible to manage three tests. Two girls, who we for this test will call Carla and Susie and one boy who we will call Simon. They all attended third grade.

Figure 35: Testing day one

The pupils were selected one by one by their assistant teacher. This was to ensure that the pupils did not interact too much with one another, where they spoiled what was going to happen. After entering the room, the pupils were greeted and put through a pre-test interview, where they had to answer basic questions. The questions were based on their knowledge of augmented reality and whether or not they had ever used any form of application for learning.

After going through the pre-test interview, the pupils were given a smartphone and a tablet. They could pick the one they preferred. They all initially wanted to use a tablet. Picking the tablet was probably due to them never having been able to use a tablet at school, which made it look fun and exciting. After spending a few minutes with the tablet, they all ended up using the smartphone. This was due to their small stature, strength, and lack of muscle control, which made it hard to handle when interacting with the digital elements of the application. When using the tablet, the pupils were also immobilized, where they had to use both hands to hold and maneuver the tablet. This sometimes made it hard for the tablet to pick up the reference point in the pages, as the pupils had little control over the big tablet.

After the pupils had tested the application, they were given a post-test questionnaire, where they had to give their opinion of the experience, the application and augmented reality. The pupils were in general very excited about the project, wishing that they could have books like this at school. They were all positive that they would have more fun, achieve more, be more interested in the subjects taught using this kind of application compared to a standard 2D book. As all of the pupils were very satisfied with the application, there was little constructive feedback that could improve the application. Most of the comments were regarding visuals, where they wanted more of everything, and one pupil wanted the ability to see how the eggs of the different dinosaurs looked like.

Day two picked up where the first day of testing ended. This time, two pupils were tested, one boy and one girl, who we for this test will call Mia and Tom. One from third grade, and one from fourth grade. The first pupil started without any interest in either the application, as Mia had no interest in digital devices or the questionnaires. But after reluctantly going through the first pre-test interview and accepted to start the application, she dove into her own little world. Mia preferred using a smartphone, as that was what she was used to and found it easier to use. After giggling her way through the application and all the pages, she was as she said; "converted." She found the application very enjoyable and would love to use it both in her spare time and at school. She even gave a hug. The only thing she wanted to improve about the application was to add more details, as in more grass, flowers, rocks, and environmental effects. For instance on a page where an asteroid is colliding with earth during the Cretaceous period, to display more of the explosion that happened during the event and the earth cracking.

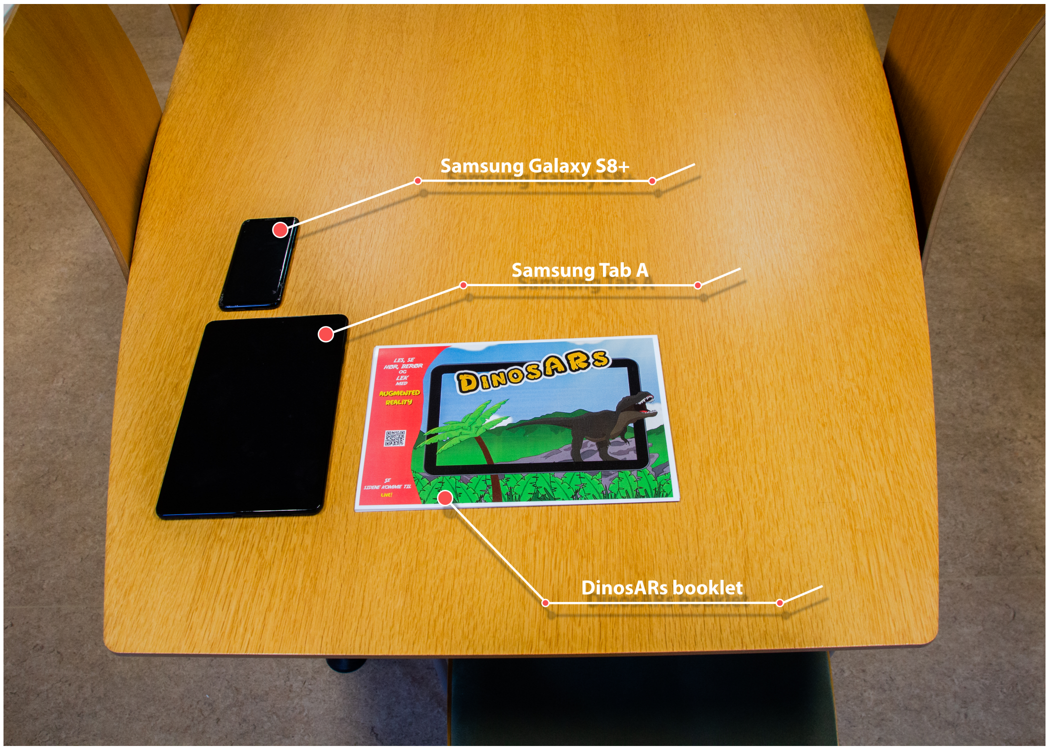


Figure 36: Testing day two

Tom, the second pupil was a person with a lot of love for dinosaurs, who was very excited about trying the application. After happily going through the pre-test interview, he started to play with the application and booklet and as many others before him, he preferred using the smartphone. He was one of the first people to read the information boxes in AR. When asked if he could choose between using both a smart device, paired with the booklet or simply just a smart device, he said that he wanted to pair them and use both, as it made him feel like the dinosaurs lived in their own small world.

Getting the pupils to be able to participate in testing is something that could at times be difficult. Pupils in primary school have long breaks between classes, mandatory gatherings others things they have to attend to. On day three of testing, the testing of the last five pupils managed to take place. While testing with the fourth-grade pupils, each session also seemed to go by much quicker, as they seemed more independent. When going through the questionnaires with the third-grade pupils, most of them waited for me to read the question and ask them of their opinion. On the other hand, the pupils from fourth grade usually just started to answer the questionnaire on their own, with little or no explanation. This might be because of stronger reading capabilities, as they behaved much more independent.

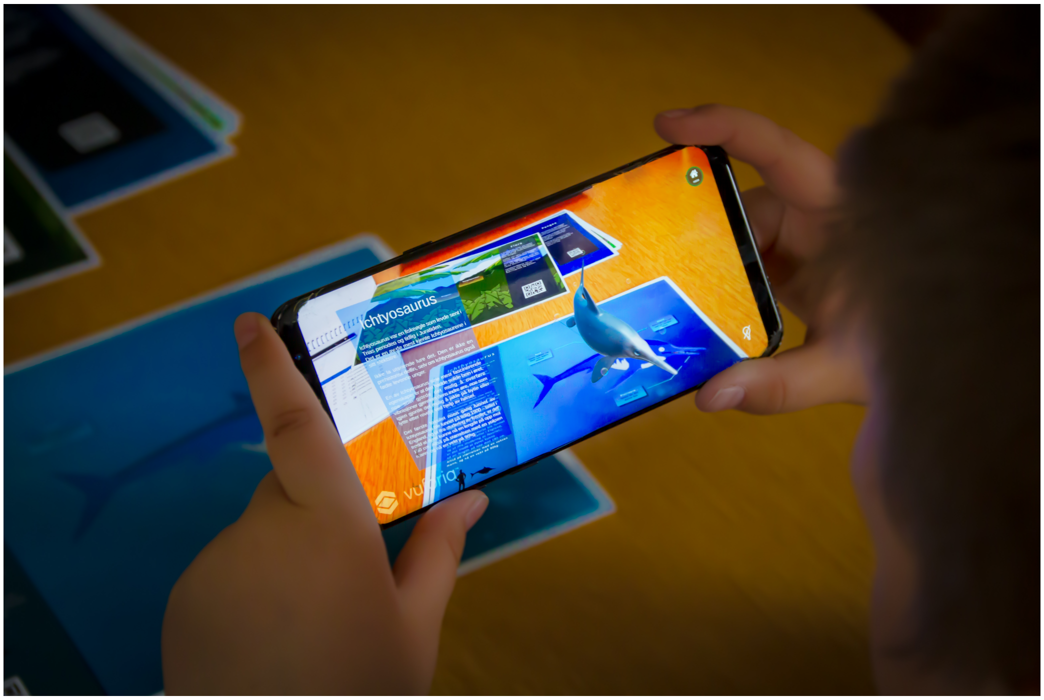


Figure 37: Pupil testing the DinosARs application

On the third day of testing, the first test participant of the day was, who for this test will be called Angela, the last third-grade pupil. Angela seemed uncomfortable and withdrawn before starting the testing. After shyly going through the pre-test interview, she opened the DinosARs application. She was the first pupil to read the instructions before pressing start in the main menu, which made it somewhat more comfortable for her to understand what she was supposed to do when starting the AR experience. She seemed more relaxed and engaged when playing around with the dinosaurs.

The pupil of the day, who for this test will be called Greg, was the pupil with the most superlatives in the whole test. The assistant teacher said that he had been excited for weeks and was looking forward to testing the application. The first thing he said after sitting down was; "Wow, I'm looking forward to reading this." Greg took his time with every page, reading the material and studying whatever aspect of the dinosaurs he could, wishing that he could see them in real life, saying that it inspired him to do more research about dinosaurs. He also found the post-test questionnaire fun and exciting. It seemed to increase his interest and motivation to engage with the learning material for self-directed learning.

The third pupil, who for this test will be called Tommy, was the most energetic and unfocused of the bunch. Even before being delivered the pre-test questionnaire, he was halfway up on the table. As seen down in figure 38, things didn't help after he was handed the questionnaire either.

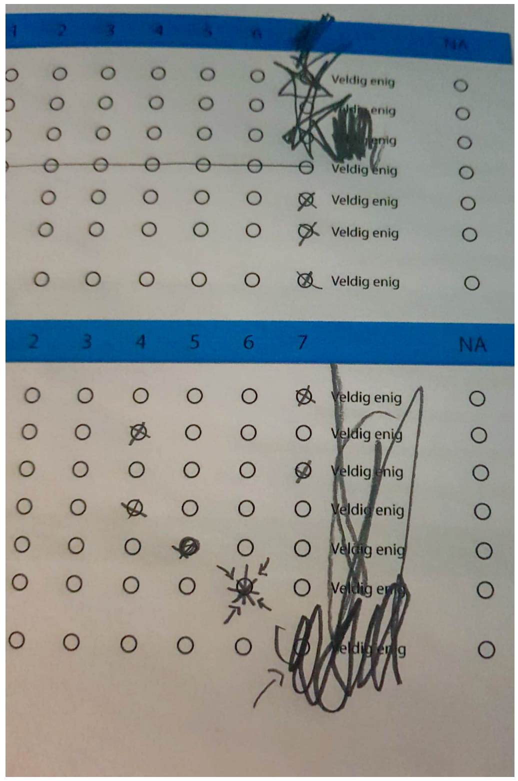


Figure 38: pupils questionnaire

Things improved when he got the tablet. Tommy sat down in his chair and started focusing on the pages. He smiled and laughed as he went through the different pages, looking at the different species of dinosaurs and their world. He also asked questions about dinosaurs and the application. He seemed focused and entertained. Things started to fall apart again when he received the post-test questionnaire. He once again lost all interest and was once again half way up on the table. After finally getting through the questionnaire, he asked if he could try the application one more time before the next person came in. He then seemed to calm down again and went into his own little bubble, where dinosaurs were more interesting than the outside world.

The fourth pupil of the day, who for this test will be called Melanie, didn't know what she was participating in, other than it had something to do with a smart device and dinosaurs. She seemed to enjoy the test as soon as the pre-test questionnaire started, and things got even better when she was able to use the DinosARs application. Melanie initially wanted to use the Samsung tablet, but after a few pages, she asked if she could try the smartphone. After using both, she said that she liked the smartphone better, due to it being easier to handle, maneuver, and interact with. It also has better hardware and a better camera, which might give a better user experience. She also preferred reading the digital pages, and would if she could choose, only use smart devices for interacting with augmented reality.

The fifth and final pupil of the day, who for this test will be called Kevin, was in his own words; A self-declared nerd. Kevin said that he was really into dinosaurs and was very fond of explaining what science and technology could do today, and in the years to come, which mirrored in his enthusiasm for the project. He has also recently been to a museum for dinosaurs and was therefore excited to see if he could recognize any of the dinosaurs in the application, which he did and very clearly expressed. After going through them all, he expressed a desire for more pages and was quite sad when there weren't any left. He pointed out that he would have done homework for the whole week in a day if he had augmented reality books. He also would like to see online AR, where he could do homework with his classmates.

After spending a few days together with the pupils, I learned a lot about how an AR application works in real life, and on the audience, it was aimed at. I also learned how the pupils interacted with the application, technology, and content.

Overall the testing felt like a great experience, both for me, the pupils and the staff that was involved. The pupils were all eager to participate, and the ones who could not participate, wanted me to come back. I even got a few hugs. All the children expressed a wish that the school should acquire AR books. All in all, it was a fun and enjoyable experience, full of learning for all parts.

4.4 User experience and technology evaluation

In total, ten pupils participated in the user testing. Five girls, and five boys from both third and fourth grade, where three girls and two boys attended third grade and three boys and two girls attended fourth grade. They all had to go through a pre-test and post-test questionnaire, where they could give a score from one to seven, based on how much they disagreed or agreed with the given statements. Based on that, the boys and girls scores are divided into two groups, where the figures below show the average score on the Likert scale that the pupils scored. It also shows the average of both groups combined. The genders are divided into two separate groups to more easily see if there are any differences in behavior, interest, or skills of AR technology based on gender.

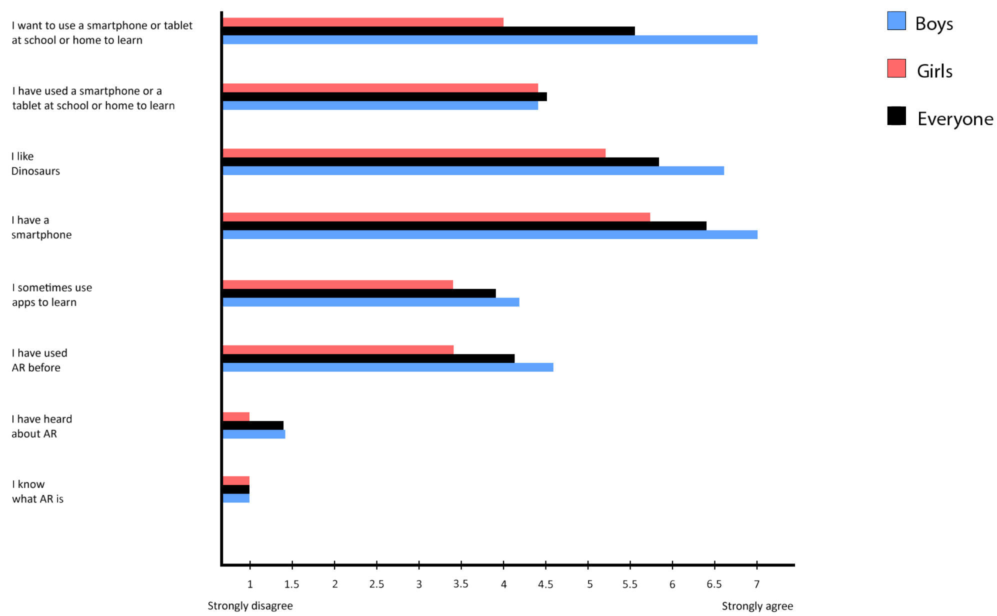


Figure 39: A general introduction of the pupil.

Based on the answers given by the pupils, we can conclude that no one knew what AR is, and only one person had ever heard about it. But, a few of the pupils had experience with using AR, in the form of Pokémon Go. Two girls and three boys had played the game. The same goes for the number of pupils that used applications for learning purposes, where two girls and three boys used applications to learn. Surprisingly enough, everyone except one pupil owned a smartphone. The sixth question about the pupils' interest in dinosaurs was favored by the boys, where they had a higher score compared to the girls.

The school where the testing took place was a relatively new school, with pupils only ranging from first to fourth grade, and therefore did not have much technological equipment. Some of the pupils, three of them girls, and three of them boys who had used smart devices for learning purposes, even though it was not regularly. They expressed through the questionnaire that they want to use smart devices more in the teaching. Especially the boys were very enthusiastic; all of them wanted to use smart devices for learning. on the other hand, only three girls wanted to use smart devices in teaching and one of the positive ones of them was not even that excited about it.

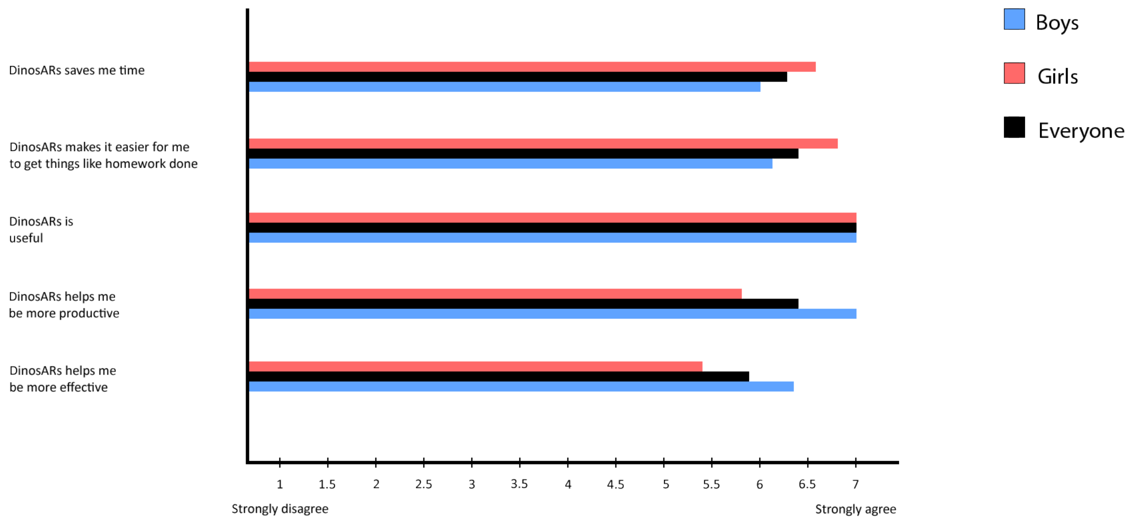


Figure 40: The pupils perceived usefulness of AR technology and the application.

After spending time with the application, exploring the different pages, interacting with the dinosaurs, and learned about their world, the pupils got the second questionnaire. Here, the pupils had to rate the usefulness of the application. Both groups agreed that it was a useful application, where they both gave a perfect score. The boys gave a slightly better score when it comes to being effective and productive, while the girls gave a better score when it comes to getting homework more easily done and that it may save them time.

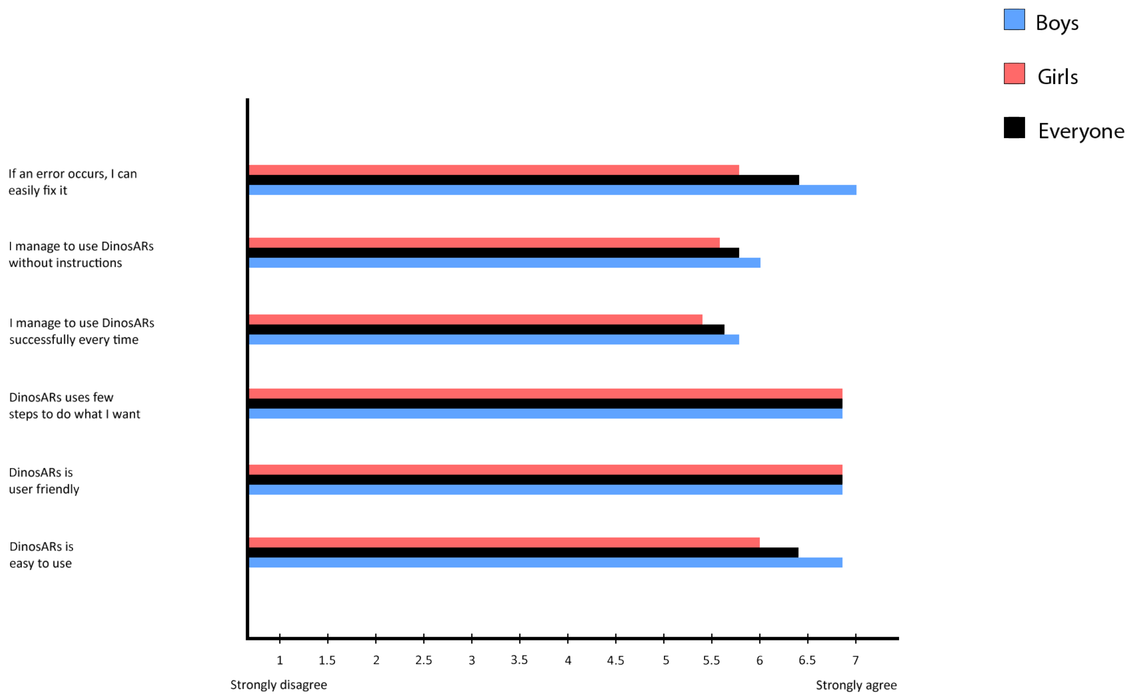


Figure 41: The pupils perceived ease of use of the application.

In the second part of the questionnaire, the pupils had to score the ease of use of the application. Both groups scored fairly high in every aspect, but the boys seemed to be more positive, as they scored higher than the girls on every question. The group of boys also seemed more interested in the technology from the start which may support the information given by the OECD [25], which may indicate that they already had an interest for technology, smartphones, and digital devices in general, which might have made it easier for them to understand what to do.

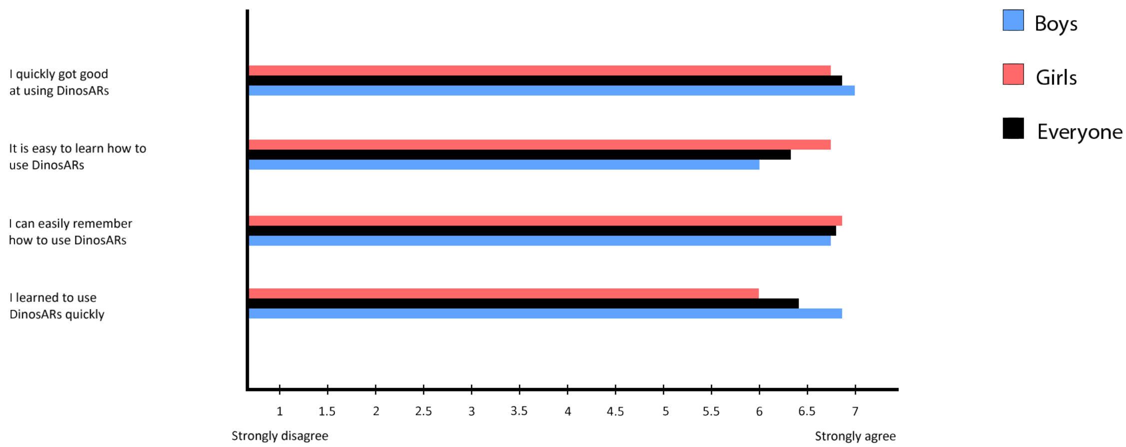


Figure 42: The pupils perception of how easy the application is to learn.

Both groups did, in general, get the hang of using the application and AR reasonably fast, but the boys seemed to get the hang of it just a tiny bit faster than the girls. But the girls, on the other hand, seemed to find it easier to learn how to use the application. They also found it easier to remember how to use it.

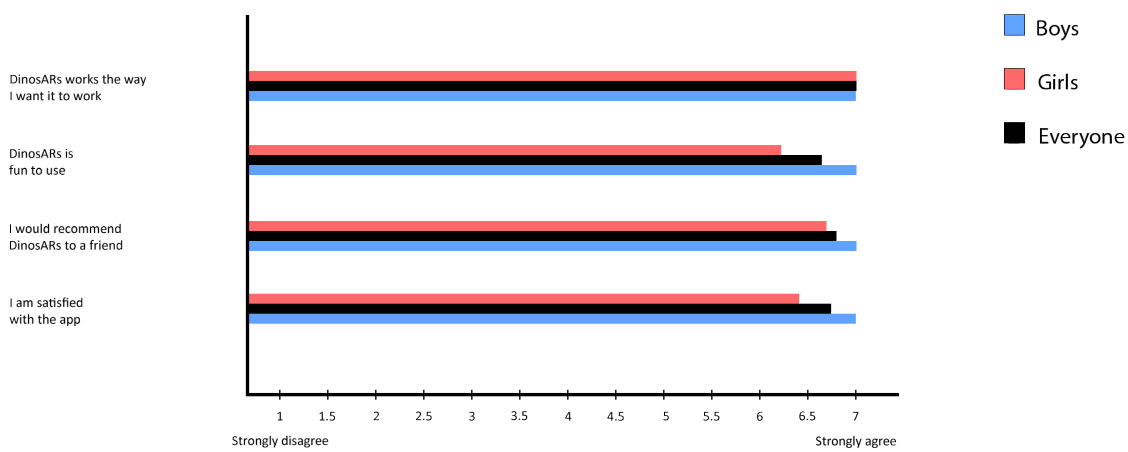


Figure 43: The pupils perception of how satisfying the application is to use.

When it comes to satisfaction, the boys seemed to find the experience just slightly more interesting, fun and satisfying compared to the girls, even though both groups gave a high score of approval on every question.

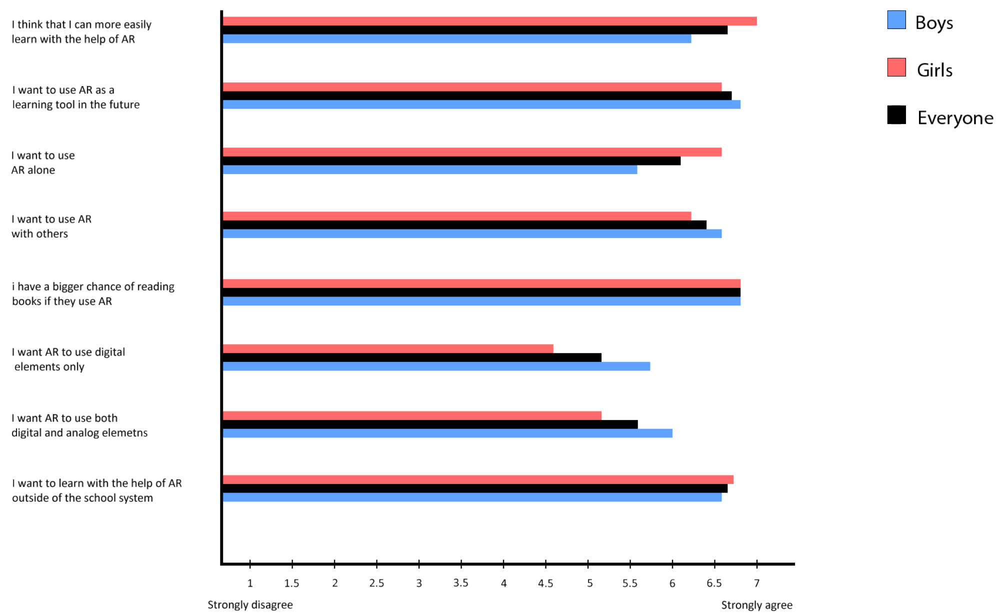


Figure 44: The pupils general attitudes towards AR technology.

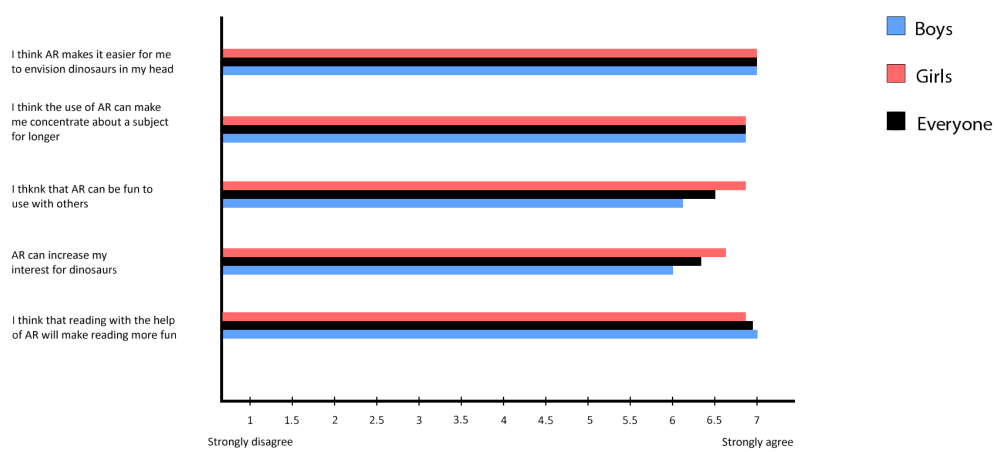


Figure 45: The pupils general attitude towards AR after using the application.

In the last and final questionnaire, the pupils were asked more general questions about their experience of using AR and what they would like it used for in the future.

The first question asks if the pupils want to learn with the help of augmented reality outside of the school system, where both groups almost gave a perfect score. All the pupils found the technology exciting and wanted to experience and use it on their own.

The two next questions ask how the pupils want to interact with the content. Does the pupil want to have the ability to use paper, a physical material that they can see and touch, or the ability to only use a digital device to display AR models? On this question, the boys seemed to have a stronger opinion compared to the girls, as they gave a higher score on both questions. It looks like the boys like to have the physical paper as learning material, but they also do not mind only using a digital device. The girls, on the other hand, gave both questions a lower score. They seem to be less satisfied compared to the boys at interacting with both digital and physical material. If they had to choose one, they seemed to prefer having the physical paper.

The fourth question asks the pupil if they are more likely to read if the books are enhanced with AR, where both groups strongly agreed to the statement. They liked the idea of being able to see the stories come to life up through the pages as they read and got excited about it.

The next question asks the pupil if they would like to use AR with others. Due to time limitations, I was not able to test the application in groups, but I still got to see how the pupils excitedly interacted in the hallways, telling one another how fun it was. On the question itself, the pupils strongly agreed that they would like to use AR with others. The sixth question also asks if the pupils would like to use AR on their own, where the boys scored higher than the girls, which indicated that the boys had no specific preference of working in groups or alone with AR and that they found both ways enjoyable, while the girls preferred to work in groups.

The next and seventh question asks the pupil if they would like to use AR as a learning method in the future, which all the pupils highly agreed to. They told me how they were going to ask their teachers and principal to start using AR as a learning tool in classes, and that they found it very enjoyable.

On the eight-question, the girls scored higher than the boys in the regards of AR, making it easier for them to learn. The girls did, in some cases, find it more interesting to read about the dinosaurs rather than look and interact with them.

The ninth question asks the pupils if they think AR can make reading more fun, where both groups highly agreed, thinking back to question four where they liked the idea of books coming alive.

When asking the pupils if AR could increase their interest in dinosaurs in the tenth question, the girls did again get a higher score than the boys. This might be because the girls were not that interested in dinosaurs, to begin with, and that AR made dinosaurs seem more attractive to them, while the boys already found dinosaurs to be fun and exciting and therefore did not gain as much interest as the girls did.

On the eleventh question, the pupils were asked if they think AR can be fun when used with others. Both groups strongly agreed, with the girls receiving the highest score.

The twelfth question asks the pupil if they think they would be able to concentrate on a subject for longer with the help of AR. Both groups gave an almost perfect score with thirty-four out of thirty-five points. The pupils told me that they would start considering homework and classes as fun, instead of as a chore, and therefore something that they would do on their own initiative.

The last question asks the pupils if they think AR can make it easier for them to envision dinosaurs in their head. This is something every pupil agreed with and found very helpful, as it made it easier for them to see details and features of dinosaurs that were hard for them to notice otherwise in books they had previously read. Every pupil gave the question a perfect score.

4.5 Pupils perception of the AR solution

By adding together the score of every answer given in the USE questionnaire [28] (usefulness, ease of learning, satisfaction, and ease of use) for every pupil we can get a percentage of what the pupils scored in each category. We can also segregate the scores and see how each gender scored compared to the other in each separate category, as seen below in figure 46.

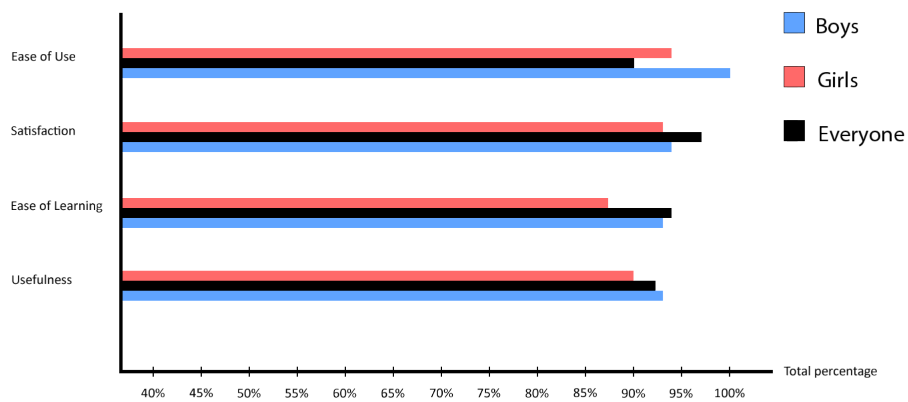


Figure 46: Combined score of every pupil based on USE parameters

1. The first category, usefulness, got a total score of 321/350 points, which is a total of 92 percent. The pupils found the application and technology useful and had several areas they wanted it applied in. They wanted the technology to tell stories, help them with math, draw 3D pictures, visualize things, and much more. The pupils were good at finding things they thought the technology could be useful for. We can also separate the two groups and see how each gender scored. For usefulness, the boys scored 163/175 points, and a percentage score of 93 percent. The girls suggested lower score of 158 points, and a percentage score of 90 percent. The outcome seems to portray that the pupils found the application and technology useful.

2. The second category, ease of learning, got a very high score considering it was the first time any of the pupils had used AR other than Pokemon Go in a few cases. It received a score of 262 out of 280 points, ending up at 94 percent. The pupils quickly got the hang of how to use the application and did an excellent job of successfully maneuvering through the application and finding the dinosaurs on the pages. Here the boys got a score of 132/140, with a percentage score of 94 percent. The girls got a score of 130/140 possible points and a percentage score of 93 percent. Once again, the boys scored a higher score than the girls by a small fraction. The scored seems to indicate that the pupils found the application and technology easy to learn.

3. The third category, satisfaction, received the highest score of all in the USE questionnaire[28] with a score of 271 out of 280, ending up at 97 percent. The pupils were all happy with the experience and the application, running around to their friend who did not get to try, telling them about how it worked. The boys scored a perfect score with 140/140 points. The girls also scored a high score, but still lower than the boys with 131/140, ending up at 94 percent. The score seems to indicate that both groups were satisfied with the application and technology.

4. The fourth and last category, ease of use, got a score of 378 out of 420, which translates to 90 percent. Only one pupil took the time to read the instructions, but even so, all of them managed to track the pages and display the dinosaurs. They also found it easy to use, and user-friendly. The pupils sometimes lost track of the pages, but easily managed to fix the problem, which required them to re-adjust the camera so that it could once again track the pages. The boys ended up with a score of 196/210 points, which equals 93 percent. The girls scored 182/210 points and ended up with a percentage score of 87 percent. The boys once again scored higher than the girls, but both groups seemed to find the application and technology easy to use and operate.

By looking at the scores on figure 46, we can see that the girls scored lower than the boys in every category, from usefulness, to ease of use, to ease of learning, and lastly, satisfaction. This might indicate that the girls, even though they scored high in every category, may have less effect compared to the boys when utilizing AR for learning. We can also see how the boys scored compared to the girls, and as seen, they scored higher on every question. This might indicate that the boys might have a better dividend for using AR as a learning tool. They found it more useful, easier to use, easier to learn, and that it gave more satisfaction.

5 Findings

Having tested the application and technology with the pupils gave a good understanding of what the technology can do to improve the learning experience of pupils when interacting with AR. Based on the information gathered, we can give answers to the research questions that were established at the start of the thesis.

1. How can the use of AR, support the implementation of student-centered learning in primary school?

1a: Is student-centered learning in primary school too soon?

Based on the testing at Blakstadheia primary school, where ten pupils participated in the test of the application DinosARs, I have found signs that may indicate that AR can support the implementation of student-centered learning in primary school by letting the pupils take control of their learning content. Like Liu, Dede, Huang, and Richards explained earlier [12], about how VR may benefit from utilizing constructivism, so may AR. With the use of AR, placing the student in the center of learning and teaching. AR lets the pupils enter a world where the content can be a guided tour. On this tour, they can either in pairs, groups or on their own, let the content teach them. Testing also suggested that AR may also increase intrinsic motivation. The pupils were very positive in implementing AR for educational purposes. Some pupils would also like to use AR technology to learn in their own spare time.

During testing, all of the pupils were quick to find out how to use the application, which may indicate that primary school pupils are not too young to use AR. They might, on the other hand, be too young to handle a big tablet. When given the tablet, they were left quite static due to its size, limiting their ability to interact with the screen and maneuver it around. Even though in a lot of cases the tablet was their first pick, as it delivers a bigger display and is more uncommon than a smartphone, which seemed to make it more appealing to the pupils. Using a tablet for AR at primary school education might work if the tablet is placed in on static stand, and the objective is to move the object that is augmented and not the device itself. At Blakstadheia primary school, almost all of the pupils had their own smartphone. In this particular case, this makes the technology very obtainable. It may also indicate that more and more young children are obtaining smartphones, which is something that makes AR usable in virtually any environment.

2. How can AR enhance or increase the learner to content interactions for self-directed learning in primary school?

   2a: Would pupils be more motivated to study outside of school if they had the ability to use AR?

While testing with the pupils, it was indicated that AR may enhance or increase the learner to content interaction for self-directed learning in primary school by letting the student take advantage of the multimodal learning experiences that AR can provide. AR combined with a physical material like the DinosARs pages, can deliver an experience that would support VARK learning styles [3]. This could make it easier for more student to enjoy interacting with the content, making them take more ownership of their own learning. During testing one of the students seemed to have some form of attention deficit problem. He was all over the table, not being able to focus on the task given to him. This changed when he got to play with the application and booklet. This may suggest that AR can support different learning styles and support students with forms of attention deficit problems.

Pupils also strongly agreed that they would be more motivated to study outside of school if they had the ability to use AR, as seen in figure 44. Some of the pupils wished for the school to supply them with AR books right after leaving the controlled test environment so that they could bring them home. Some of the pupils even said that they would study regardless if it was homework or not.

3. How does AR affect the learner experience in interacting with printed learning material?

   3a: Would pupils like to combine digital and printed material, or keep them separate?

   3b: Do pupils see any added value/benefits of using AR combined with printed material /Book/physical material?

   3c: Are pupils more likely to read books if they are supplemented with AR?

The pupils interacted with the printed learning material in a manner that they were not used to. A page was no longer just a page. It is no longer locked in two dimensions but is supplemented with a third. As one of the pupils mentioned; He viewed the pages like a "home" for the dinosaurs to live in, which may suggest that the pupils get a more personal connection to the printed learning material. With AR, you are able to give the printed material a personality. The users also seemed to spend more time than they would otherwise do if it was not augmented. When reading a normal page, the reader would usually turn the page when they are done reading, but with AR, the user is now able to view the page from different angles, interact with the material and listen to different sounds, which gives the reader a whole different experience.

When asked if the pupils would like to combine digital and printed material, or keep them separate, most of the pupils opted not to have that much interaction with the printed material, other than going from one page to the other. As mentioned above, pupils still liked the idea of having a physical material to interact with, as it functioned as a "home" for the dinosaurs to live in. They also did not mind the idea of only using a digital device. It seemed to depend on their relationship and experience that they had of books before taking part in the test. The pupils who regularly used books preferred to have printed material. The pupils who usually did not have a good relationship to books, on the other hand, preferred to only use digital devices if possible. When going through the pages, only one of the pupils took the time to read what was written on the pages. The other pupils were more interested in the digital elements on the pages. For instance the dinosaurs, animations, and sounds, rather than interacting with the pages themselves. None of the pupils had any previous knowledge of AR other than some of them playing Pokémon Go without them knowing that Pokémon had anything to do with AR. This might affect their lack of interest for the printed material and their excitement for the digital elements.

Regardless of the pupils' experience and fondness of books before taking part in the test, everyone strongly agreed that they would be more willing to read books if they were augmented. All pupils were very positive to the idea of their favorite book characters being able to come to life through the books. They all wanted to see the castles, spells, and animals from stories play around on their book pages.

4. Can AR help close the gender gap in education, where one gender performs better than the other?

    4a: Does AR help boys be more engaged in classes?

    4b: Can AR be used as a learning tool for both genders?

The study involved boys and girls to see if AR technology would affect and interest the two groups differently. Based on the tests that were done, it may be suggested that AR could help boys stay focused and interested in the learning materials. It would also suggest that AR could help boys be more engaged in classes. The pupils seemed to have a lot of fun playing with the application and in some cases, the application seemed to turn the unfocused and energetic participants into calm pupils who wanted to learn more about dinosaurs. They also scored higher than the girls in the USE questionnaire and seemed more interested in the technology and its possibilities. Answering if the technology can help close the gender gap in education, where one gender performs better than the other, requires a lot more participants than this thesis had time for, but the smiles on the faces of the boys who participated may indicate that it is at least something that should be looked further into in the future.

This does not mean that the technology does not suit the opposite gender. The girls also gave a lot of positive feedback, where they all were surprised by how fun and interesting the technology and application was. The technology may even out some of the aspects where boys and girls differ from one another as provided in the list by (OECD)[25] where for example boys are more likely to play video games, and girls are less likely than boys to spend time on computers and internet. AR might be a technology that makes both genders want to read, play, do homework, and learn. Going back to Morville's user experience honeycomb [6], we can conclude that everyone found both the application and technology usable. The pupils fond both DinosARs and AR easy to understand and their learning curve was short and painless. The pupils also found it useful, and felt that it could fill some of their educational needs. They also found it desirable. AR is still new to most users, which may fill the user with an extra sense of excitement resulting in the user wanting to keep using it.

Making it findable, accessible and credible is something the application and technology may still have to work on. During research of this thesis, coming over material is still hard to come by [21]. It might still have to find its place for educational purposes. Future research might still be needed on where it can fit in. AR still has to build a reputation for being one of the go to tools as a learning concept. Maybe this can help it becoming more credible, and therefore more accessible and findable.

During testing, the importance of having a good tracking point also became apparent. Some of the pages for the application did have a higher Vuforia targeting score compared to some of the others, which in some very few cases showed during testing. Having a higher Vuforia score means that the application has an easier time tracking the marker due to the marker having a more recognizable targets. Having the correct paper type is also something that turned out to be important. It should be as matte as possible to avoid glare from light sources in the room. During testing, two types of paper were tested. Gloss photo paper, which gave a much prettier look to the pages and also made them more durable and gave a higher feel of quality, but it did also catch more of the light that was in the room, resulting in glare. The other type of paper was standard matte print paper, which gave away less glare for a better tracking experience, but also felt less durable and had a worse overall feeling to it. In the end, for a good tracking experience, the paper should be as matte as possible, the camera should be of high enough quality to able to pick up all the details on the page and a light who is not too bright.

Using the Samsung Tab A also showed that even though Unity may handle a big amount of polygons, this does not mean that the device running the application does it. A large number of polygons may lead to the device spending an extra second or two loading the 3D model. After targeting the marker, the user might end up readjusting the camera, thinking that they have lost the target, ending up with application actually losing the marker after having found it. This also brings up the importance of having a good Vuforia tracking score. Making sure that there are as many as possible features for the camera to track is paramount for a good AR experience.

6 Conclusion

The main research questions of this thesis focused on the use of AR to support the implementation on student-centered learning in primary school, how AR can enhance or increase the learner to content interactions for self-directed learning in primary school, how AR affects the learner experience in interacting with printed learning material and if AR can help close the gender gap in education, where on gender performs better than the other. To answer these questions, an AR booklet and an application was developed as a test pilot to pupils for testing. At Blakstadheia primary school, where 10 pupils participated. User testing showed overall positive results, with all of the pupils enjoying both the physical booklet, application and the AR technology.

From a practical standpoint, this thesis contributes in helping others to develop educational AR applications, both in and outside of the classroom. From a test participants perspective, there seems to be a demand for it. The solution developed required a great deal of previous knowledge of different kinds of software as well as new types of software, like Vuforia. It also required gathering a vast amount of knowledge of AR and its possibilities.

In the start of the thesis, Bill and Melinda Gates talked in their annual letter of 2019 [9], about how textbooks are finally becoming obsolete. During this thesis, testing might suggest that this is not necessarily correct. They might not work in the way that we are used to today, but that does not mean that they will go extinct. With the help of augmented reality, we are able to breathe life into books and give them a sense of personality that we have not been able to before. Books are able to always be up to date, and be delivered in more than one language by updating the AR aspect of the book.

AR a technology that has a vast potential, but might not have found a specific spot to plant its root yet. With the help of the test participants from Blakstadheia primary school, we can at least show positive results of where it might fit in.

7 Future work

If DinosARs were to continue development, there are a few things that would need improvement and a few features that would be great implementations. The first would be the reduction of polygons on the models. The amount is something that worked fine in Unity and on a flagship model smartphone like a Samsung S8, but when using something that does not have the best hardware, like the Samsung Tab A that was used as the secondary device that the student could pick, stuttering may appear when the application finds the tracker. This is something that may irritate the user and cause bad user experience.

The second thing would be to add more pages to each of the periods that the dinosaurs lived in. Adding more to the pages in the form of more animation to make it seem more alive, and more things to press and interact with would also be great additions. This is also something that the students would like to see.

Adding features that would make the students able to learn more about dinosaurs, like a quiz system that was based on the information gained throughout the pages, would also fit the application. There could also be a character that acted as a guide in the application, telling the students about the dinosaurs, educating them as they go through the pages. This may enable the students to be more independent, and let the teachers and substitute teachers supervise and help individuals rather than focus on educating the whole class. An example can be seen in figure 39:

Figure 47: Greenfeet, the helping dinosaur guide

Adding different kinds of features are one of the advantages of digital and AR books. Even after they are published, they are not necessarily done. The application can still be updated to offer the latest and greatest features and knowledge.

During the research, only 10 students participated in the test phase of the application. In the future, having a larger test sample may be beneficial to both the results and the technology. Expanding the age group of the pupils participants may also be a good idea. During testing, there was a small difference in how the students acted during testing based on their age group. This may suggest that results may change drastically based on what year of primary school the students are attending.

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