

Jon Hofslı

# Improving the usability of an educational augmented reality platform

Master's thesis in Industrial design

Supervisor: Ole Andreas Alsos

Co-supervisor: Attila Bekkvik Szentirmai

June 2022



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Norwegian University of Science and Technology  
Faculty of Architecture and Design  
Department of Design



## Masteroppgave for Jon Hofslie

### Design av programvare for digitale berikelser i publikasjoner Design of software for digital enrichment of publications

#### Bakgrunn:

Ludenso lager programvare som gjennom utvidet virkelighet lar brukere berike publikasjoner med digitale elementer (3d-modeller, videoer etc.). Prosjektet vil skape et nytt produkt som baserer seg på relativt ung teknologi. Det er derfor viktig at produktets er brukervennlig både på et overordnet nivå (tjenesten som helhet) og på et mer spesifikt nivå (produktets funksjonalitet, utforming osv.)

#### Oppgavebeskrivelse:

Prosjektet vil gå ut på å kartlegge potensielle bruksområder og brukere, samt å designe et produkt basert på kartleggingen og diskusjon med Ludenso.

#### Oppgavens gjøremål:

- Kartlegge brukergruppe (hvem)
- Kartlegge behov (hva, hvordan)
- Utvikle konsept(er)
- Brukertestet løsningen(e)

Oppgaven utføres etter ”Retningslinjer for masteroppgaver i Industriell design”.

Ansvarlig faglærer (hovedveileder ID): Ole Andreas Alsos

Eventuelt biveileder: Attila Bekkvik Szentirmai

Bedriftskontakt: Ludenso

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Ole Andreas Alsos  
Ansvarlig faglærer

Trondheim, NTNU, dato

12.01.2022



Sara Brinch  
Instituttleder

# Improving the usability of an educational augmented reality platform

Master thesis by Jon Hofslı

Supervisor: Attila Bekkvik Szentirmai

Responsible subject teacher: Ole Andreas Alsos

# Foreword

This master thesis is written as part of the subject TPD4900 - Industriell design, masteroppgave. The thesis was written in the spring of 2022 by industrial design Master's student Jon Hofslie at the faculty of Architecture and Design at the Norwegian University of Science and Technology.

The project is conducted with external partner Ludenso, a startup company creating augmented reality solutions for educational use. Ludenso is also the employer of Jon Hofslie.

The thesis is formatted to be optimized for a Two-Up page layout as two and two pages should be placed next to each other when reading the thesis.

# Acknowledgements

First, I would like to thank my supervisors Attila and Ole Andreas for all the help throughout the project. Secondly, I would like to thank the team at Ludenso for giving me the opportunity to work on a fun and impactful project. I would also like to thank all the research participants that took time out of their schedules to participate in this project. Finally, a huge thank you to my classmates and my partner Ingeborg for all their help in this and other projects, and for making these years of studies an unforgettable experience.

# Abstract

In this project, the usability of the Ludensos augmented reality platform has been improved through the use of a human centered design process. First, the platform and field has been researched in order to identify potential for improvement, resulting in a focus on an augmented reality authoring tool. Then, user inclusive design methods have been used over multiple iterations with the goal of identifying and resolving usability issues with this part of the platform. This included research related to facilitating good mental models related to pdf files enriched with augmented reality. Based on the results from these methods, the authoring tool, and in extention the platform, has been improved in regard to usability.



# Abstrakt

I dette prosjektet blir brukervennligheten i Ludensos plattform for læring gjennom utvidet virkelighet forbedret gjennom bruken av en menneskesentrert designprosess. Plattformen og forskningsfeltet blitt utforsket for å kunne identifisere potensiale for forbedring, noe som resulterte i et fokus på et forfatterverktøy for å lage utvidet virkelighet-opplevelser. Deretter er brukerinkluderende metoder benyttet over flere iterasjoner for å identifisere og forbedre brukervennlighetsproblemer i denne delen av plattformen. Dette inkluderte blandt annet forskning på hvordan man kan skape gode mentale modeller for pdfer beriket med utvidet virkelighet. Basert på funnene har forfatterverktøyet, og i dets forlengelse, plattformen blitt forbedret fra et brukervennelighetsperspektiv.

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Screenshots from Ludenso's software is taken and used with their approval. All other figures used in the project are made by me.

## Chapter 1

# Introduction

The introduction chapter introduces the reader to the the topic of the project as well as presenting the project goals and the plan to achieve these goals.

# 1.1 Introduction to project

## 1.1.1 Project description

This project seeks to improve the usability of an educational augmented reality (AR) platform. This is done by following a design process as described in the Methodology subchapter. The project is conducted in cooperation with the external partner Ludenso. The following goals and research objectives have been defined in order to drive and ensure cohesiveness in the project.

## 1.1.2 Project goal

The goal of this project is to improve the usability of Ludensos augmented reality platform.

This is a very broad goal, as the platform consists of several components with multiple different user groups. Having a broad project goal allows flexibility and the ability to further define the focus of the project after getting an overview.

For me this is a good opportunity to work with interesting topics within a field I already have some experience in and interest for. For Ludenso, the usability of their platform and software plays a critical role in ensuring positive user experiences with their products. Projects like this can be of great value to them when it comes to further development of their platform.

## 1.1.3 Research objectives

In order for the overall goal of the project to be reached, the following main research objective have been established:

- As stated in the project goal, the main objective of this research is to increase the usability, and in extension the user experience, of Ludensos augmented reality platform.

This objective can come off as very wide and undefined, and it has therefore been broken down into minor objectives:

- To identify in which aspect(s) of the Ludenso platform design improvements can yield the biggest results. This is important to ensure that the work done in this project is of use to the external partner, and also solves real world issues.

- Explore how a digital platform based around novel technology can feel intuitive to use for the users. The technological aspect of this project is important to consider, especially because the technology can be unfamiliar for many.
- Prototype and deliver a solution that improves upon the identified issue(s). This is important to ensure that the findings from this project are applied in a relevant setting.

### **1.1.4 Outline of thesis**

The thesis will consist of different phases, following the design process. First, the Introduction chapter lets the reader understand the objectives of the project, as well as giving an overview of, and foundation for the project and the conducted research. The Background chapter gives an understanding of the background, and the most relevant technologies and terms for the project. In the Method chapter, the different methods used in the project are introduced and explained. The Background chapter presents the insight gathered in the first phase of the project through the literature review or through cooperation with Ludenso. Insight gathered later in the project is presented in the relevant phase chapter in which it is gathered. The phase subchapters typically have the following structure:

- A presentation of the methods used for that iteration.
- Results/insight gathered during the iteration.
- Ideation/prototyping improved solutions based on the insight.

Three iterations were completed during the project, with the prototyping done during the last iteration leading to the final version of the delivery. This delivery is presented in the Delivery chapter. This is followed by Discussion, which serves as an opportunity to reflect on the work done in the project. Finally, the Conclusion chapter summarizes the work done and the findings from the project.

## 1.2 Methodology

In order to meet the research objectives for this project, a high level overarching plan for the project as well as guidelines for the methods used have been defined.

### 1.2.1 Holistic approach

As a way of meeting the research goal of identifying work that would yield the biggest result, a holistic approach has been used for the project. This means that the whole service has been considered and explored in order to understand where changes would have the largest effect. This is done by starting the insight phase with a very broad perspective, and by questioning high level decisions to how the service is planned to work. By having the whole service in the back of the mind during work on its parts, one can ensure during the work that the different parts of the service make sense together, thus ensuring consistency in the service experience of the users (Stickdorn et al., 2018, p. 26). While this project was narrowed down to focusing on specifically one part of the project, it has been important to consider how the changes impact the rest of the system, as this gives the opportunity to ensure consistency across the different platforms within the system.

### 1.2.2 Design process

With the focus on fulfilling the research objectives for this project, a process should be planned. As each design project varies, so should the design tools used (Stickdorn et al., 2018, p. 83). Still, there are some overarching patterns in how design projects are usually conducted, and these patterns will serve as a foundation for the process used in this project. These design processes often revolve around creating and reducing options throughout the project. The book “This is Service Design Doing” describes three main phases:

**Research:**

Collection of knowledge through research methods. This knowledge is later distilled into key insights.

**Ideation:**

The creation and adaptation of ideas, that through ideation methods can result in a few promising concepts.

**Prototyping/Implementation:**

Exploration and building of different prototypes, which again allow testing and evaluation. (Stickdorn et al., 2018, p. 85-86)

It is also a key aspect of this type of design process to be iterative, meaning that the steps above are repeated as many times as necessary or possible. After the first round of prototyping and user testing, the need for additional or more detailed insight might arise, creating a need to end the first cycle of the process and go back to the insight phase. This project uses an iterative process, as this facilitates continuous improvement of the product in response to user feedback.

### 1.2.2.1 Process diagram

The process diagram in figure 1 (bottom of page) presents the chronological order in which the different steps of the project were conducted.

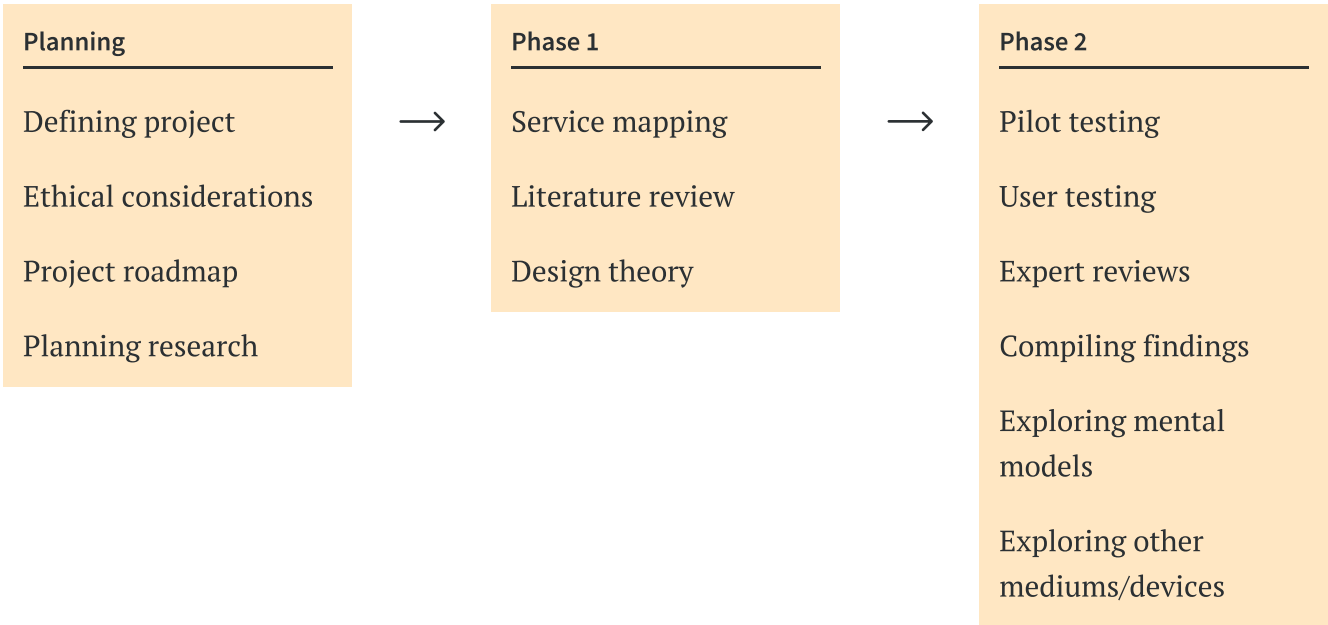


Figure 1: Pro

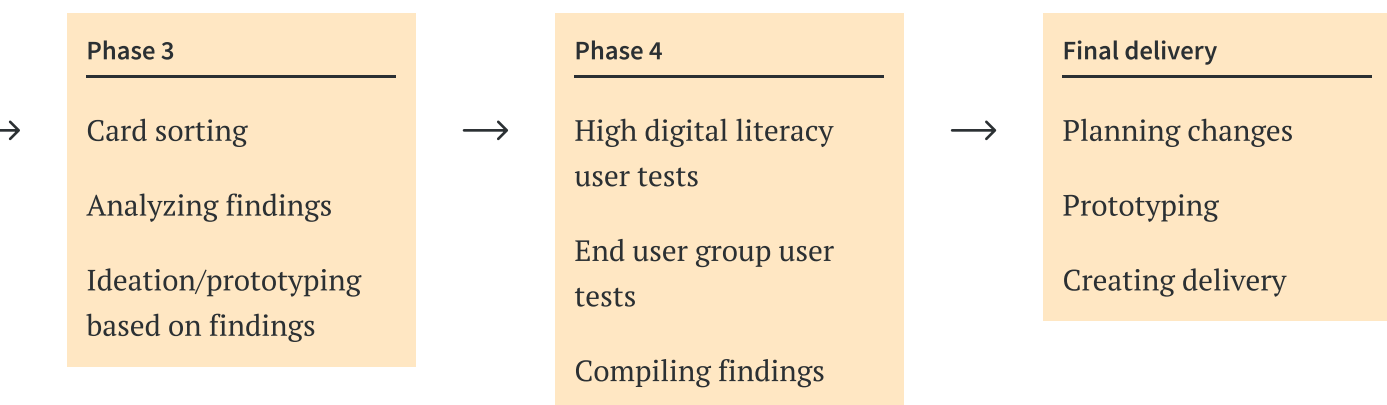


### 1.2.3 Research

The research in this project has been conducted in two fundamentally different ways.

The research on the use of AR in education as well as authoring tools has been conducted as confirmatory research, meaning the goal of the research is to confirm or disconfirm one or multiple assumptions (Stickdorn et al., 2018, p. 100). The Ludenso enrichment platform is already built on the basis of AR having value when used in education. As this is beyond my project to change, it is more relevant to understand how AR can be used to give the greatest value. The same applies for authoring tools.

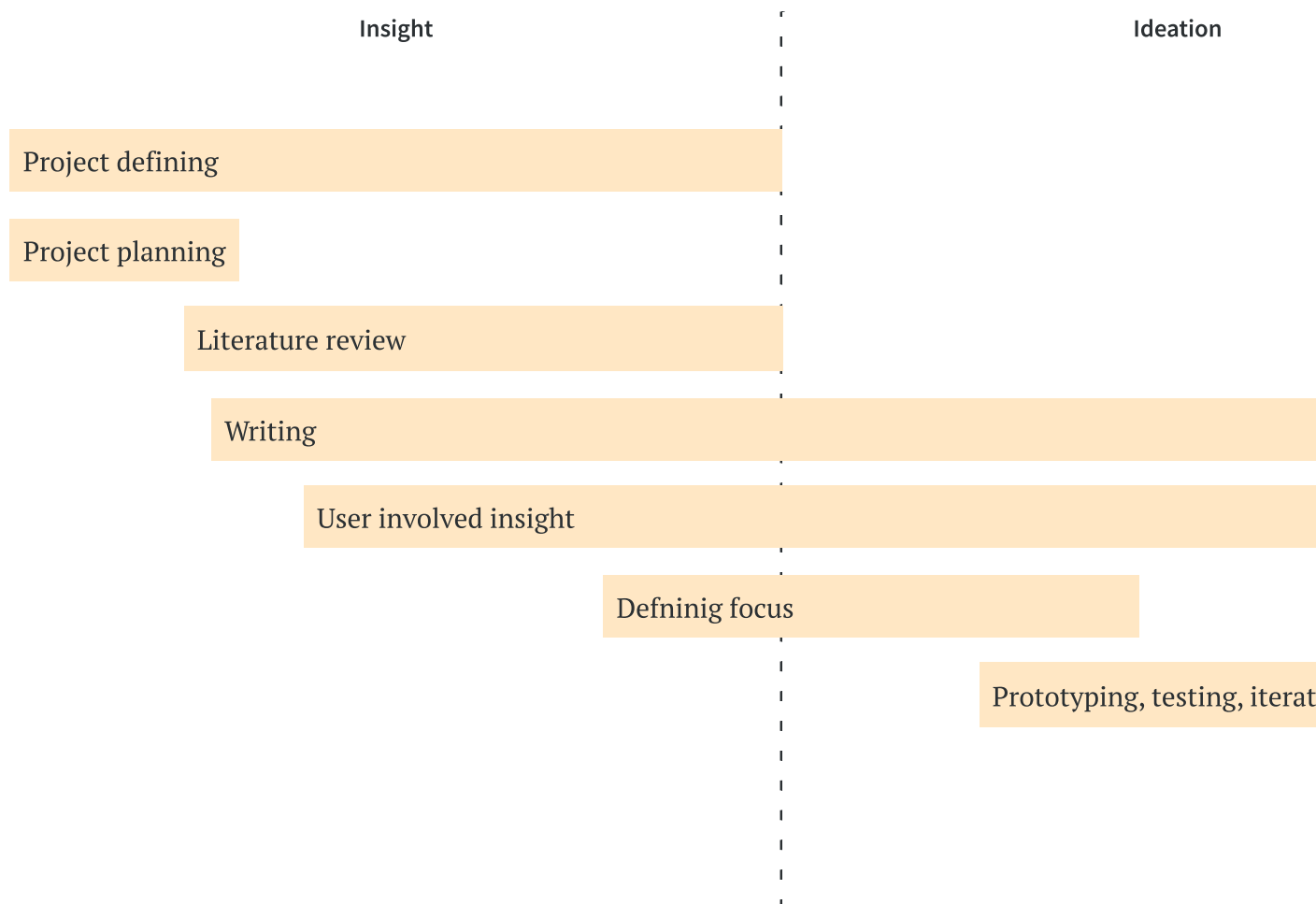
When it comes to other researched topics, these have been conducted as exploratory studies. The main goal of an exploratory study is to gain a deeper understanding of the field without prior assumptions (Stickdorn et al., 2018, p. 100).



process diagram.

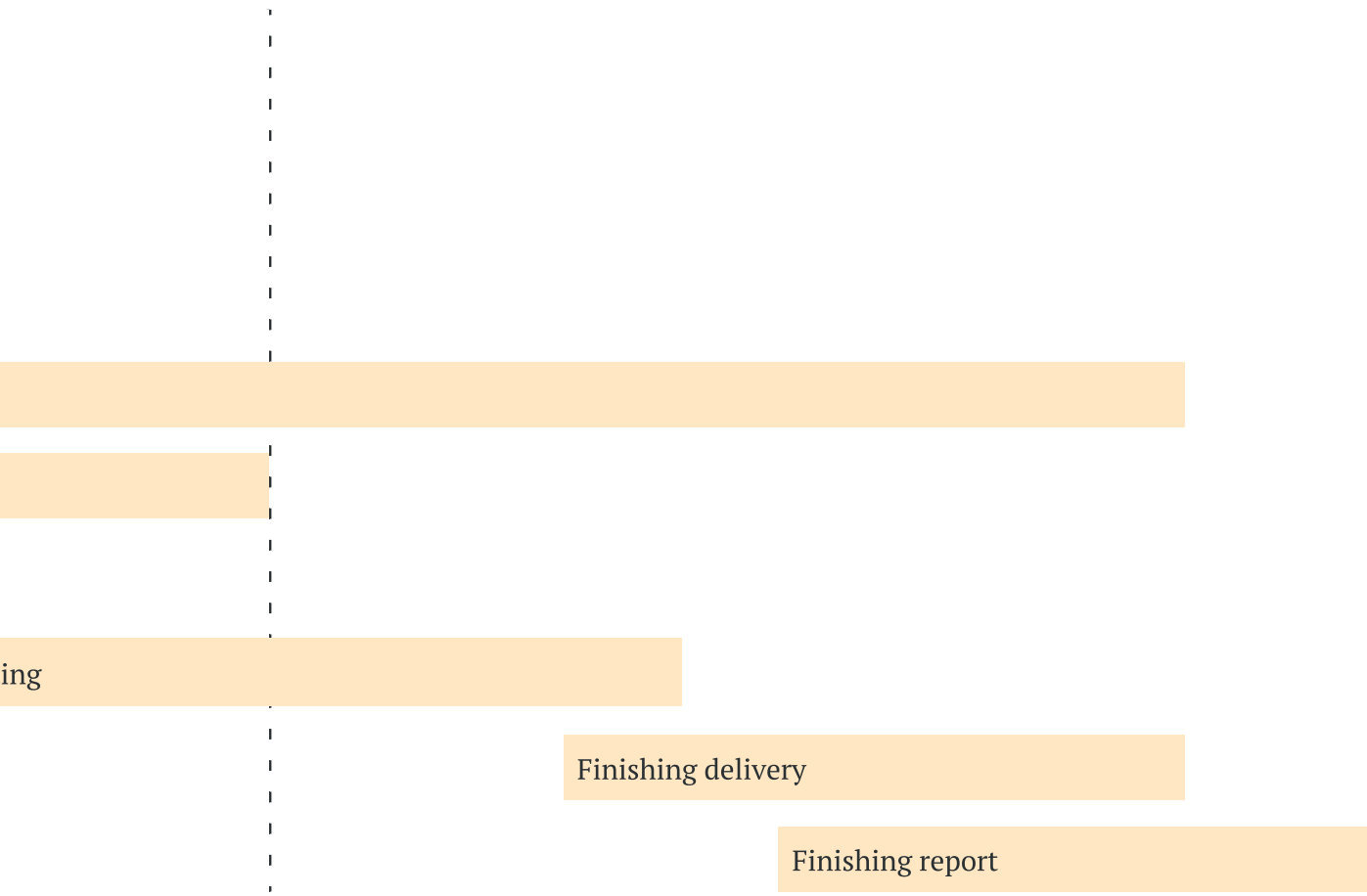
## 1.2.4 Project roadmap

The following roadmap has been created early in the project in order to visualize the process and to have a general idea of time distribution.



**Figure 2:** Pro

Delivery



ing

Finishing delivery

Finishing report

ect roadmap.

### 1.2.5 Quality assurance

This research project seeks to improve the usability of a digital platform. For the findings of this project to be reliable and usable both for contribution to a field, but also for the use of an organization, it is important that it is conducted in a trustworthy way. Therefore, some measures have been taken as a means to ensure the quality of the research conducted through this project, mainly to ensure reliability and validity, as well as reducing biases.

Reliability and validity are two terms commonly used to determine the trustworthiness of a research project. Reliability measures the extent to which a repeated trial would yield the same results, and validity relates to to which extent the research actually measures what it is supposed to measure (Carmines, 1979).

In addition, it is important to try and avoid biases in the project. Bias refers to beneficial treatment of some elements in a research at the expense of others, because of predisposed conscious or unconscious factors. For example, bias can cause an uneven sampling of participants for a project, or different treatment of the results of a research project based on how well they relate to the researchers assumptions. While it is difficult to eliminate all forms of bias, its effects can be reduced by being aware of the phenomenon. Triangulation of research is done throughout this project in order to reduce bias. This is done by either discussing findings with project stakeholders, comparing them to similar published projects and research, or using different methods for finding insight on the same topic.

## 1.2.6 Ethical considerations

The research conducted in this project is heavily reliant on user involvement. Consequently, there are some ethical aspects that should be considered. Research guidelines are sets of norms, values and arrangements, created with the goal of regulating scientific research, and they serve as a nice foundation for ethical considerations in this project (De Nasjonale Forskningsetiske Komiteene, 2019).

The research guidelines from The Norwegian National Research Ethics Committees have been used, as recommended by NTNU. The following are the guidelines along with their implications for this specific project:

### 1. Ensuring the reliability and replicability of my results

As described in the subchapter Quality assurance, any research done in the project should be conducted in a way that ensures validity and reliability.

### 2. Ensuring the value of my research

The research should be conducted in a way that is of value to the world, not only to this project. This way, the research can be shared and contribute to the general knowledge of the world.

### 3. Human focus during participant cooperation

When gathering data from people, it is important to maintain their rights. In this project, no personal information was gathered, as it was not deemed necessary for the reliability of the research. The users were informed that personal data would not be gathered, and that they would only be referred to by general terms such as “editor”.

The project involves users in several activities during the gathering of insight. During these involvements, it has been a focus to ensure the participants feel comfortable.

(De Nasjonale Forskningsetiske Komiteene, 2019)

## Chapter 2

# Background

In order to fully understand the project, it is important to have a foundation of knowledge about the external partner, used technologies and other relevant concepts. The background for the project as well as relevant technologies and terms will be introduced in this chapter. The project background subchapter presents the external partner based on prior knowledge of them as well as conversations with them in this project. The rest of the information presented in this chapter is based on the literature review described in the method chapter.

## **2.1 Project background**

### **2.1.1 Ludenso**

Ludenso is a startup company creating educational solutions using augmented reality (AR) technology. The vision of the company is to become an international market leader for AR in education. In August 2021, Ludenso launched an AR learning app, which allowed students to see AR enrichments in their school books. This project was conducted in collaboration with Aschehoug publishing house. Currently, the company is focusing on creating a platform where users can create and share their own AR experiences. This service will be explained in detail in following subchapter. I have been working part time for Ludenso since 2020 as an interaction designer. Parallel to my work on the service in this project, the Ludenso team are working on developing and improving different parts of the service.

## 2.1.2 Service overview before project

Before planning the project it is important to get an understanding of what the service and programs look like at the start of the project. This will also serve as a basis for comparison when the project is finished. This overview is based on my previous experience with the project, as well as work conducted together with Ludenso.

The planned version of the Ludenso AR platform consists of three components:

**1. Ludenso Explore (Mobile AR application):**

- a. Mobile application where users (teachers and students) can experience digital enrichments in publications (Enrichments is the term used for the augmented reality elements that are added to the pdf file).

**2. Ludenso Studio (Authoring tool):**

- a. Allows users (publishing workers) to add digital augmented reality enrichments to pdf files and publish them to Ludenso Explore.

**3. Ludenso Analytics (Analytics tool):**

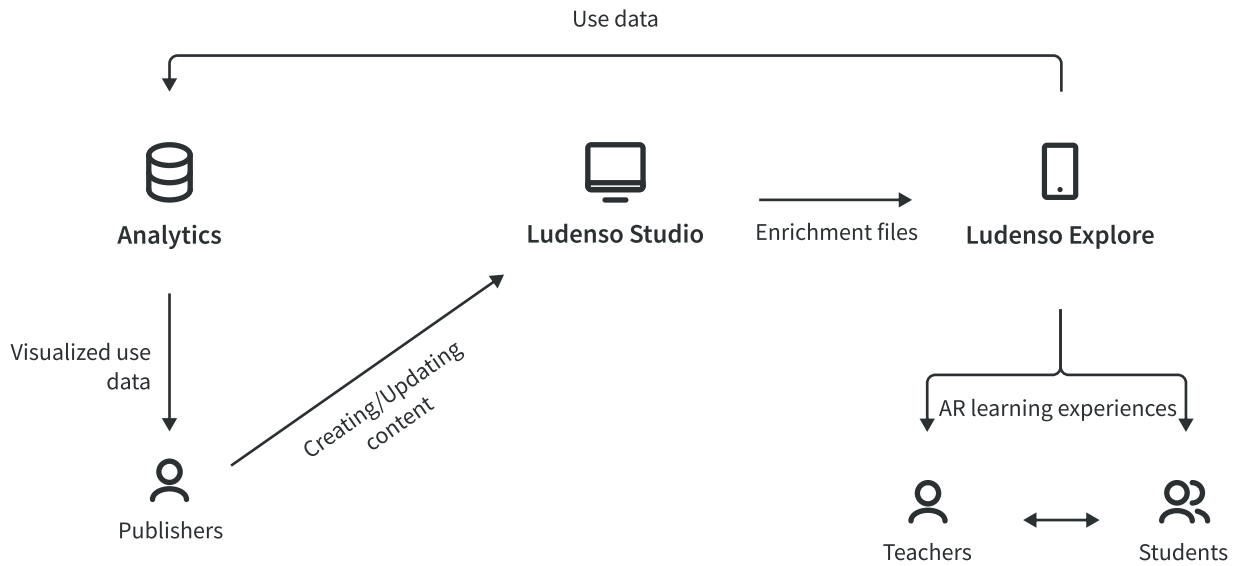
- a. Allows users (publishing workers) to get data on how Ludenso Explore is being used for their books.

Figure 3, overview of planned service, shows an overview of what the service is supposed to look like at a later time. The complete system is planned to be released some time in 2022.

Ludenso is continuously developing the software to create the planned system. The status on the three components is shown in Figure 4, component status on the next page.

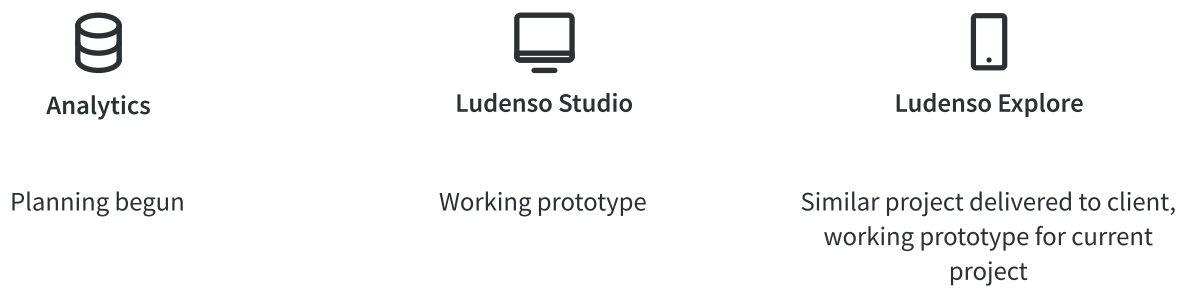


## Overview of planned service



**Figure 3:** Overview of planned service

## Component status

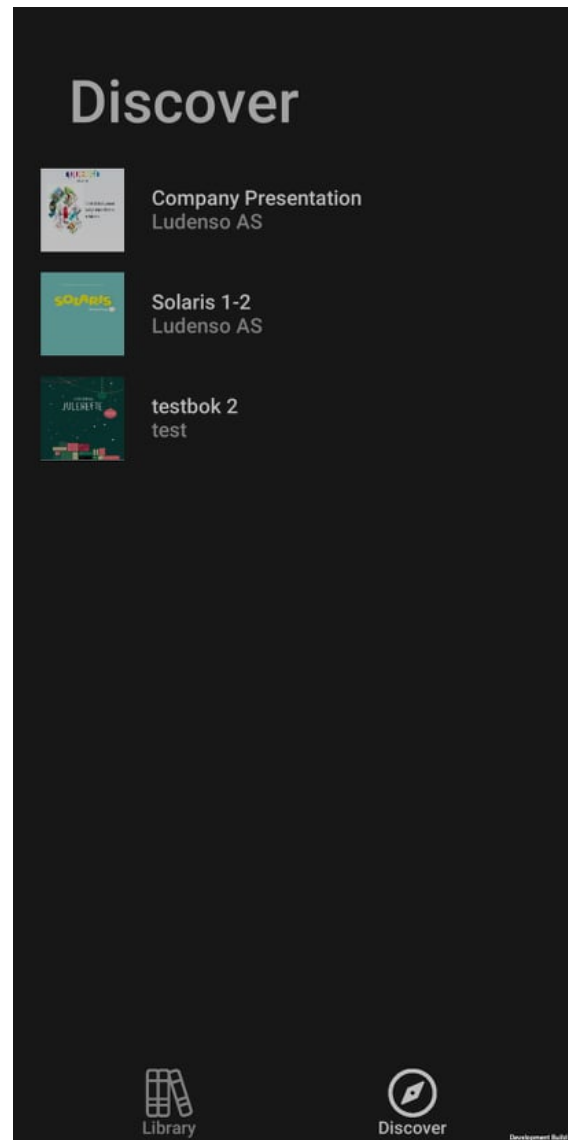


**Figure 4:** Platform component status.

### 2.1.2.1 Ludenso Explore

The Ludenso Explore app (mobile AR application) allows users to see the AR experiences created in the authoring tool.

An enrichment file is found and downloaded through the “Discover” page (Figure 5). This adds the file to the user's library. From the library, the user taps an enrichment file to open the AR view for that particular file.



**Figure 5:** Enrichment file discovery in Ludenso Explore.

In the AR view (Figure 6), the user uses the device to “scan” a page in the published media they are using. In Ludenso Explore, the pages of a pdf are used as targets for placing the correct AR enrichment. When a page from the correct pdf file is recognized, the AR enrichments are placed as defined in the authoring tool.

The user has ways to interact with the different enrichment objects through the app . 3d models can be rotated and scaled, videos can be played, paused, muted and opened in full screen mode, audio enrichments can be played and paused, and links can be clicked to open a browser window.

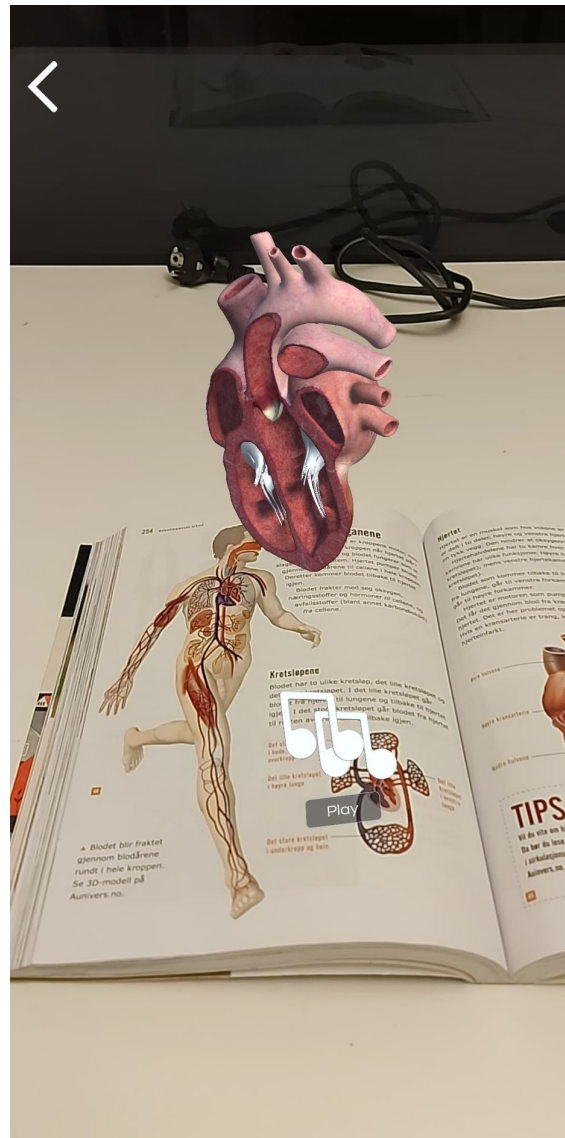
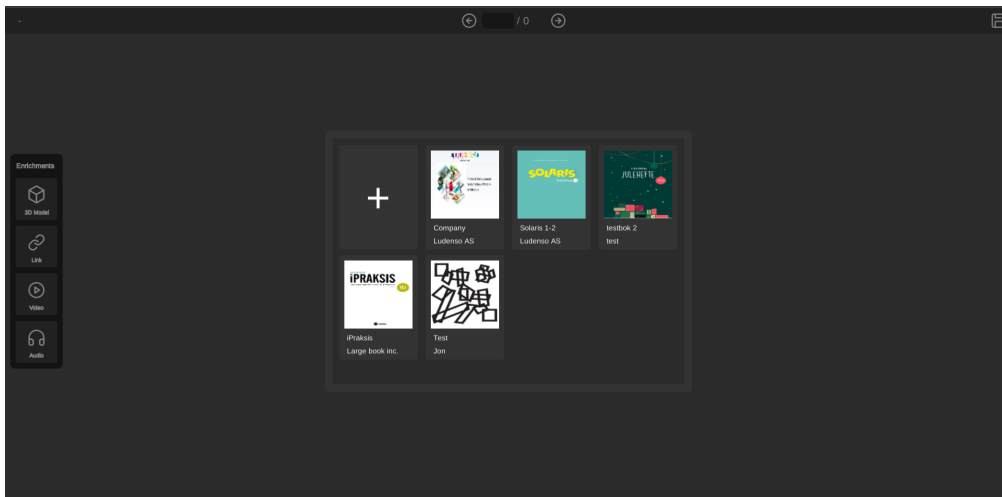


Figure 6: AR view in Ludenso Explore.

### 2.1.2.2 Ludenso Studio

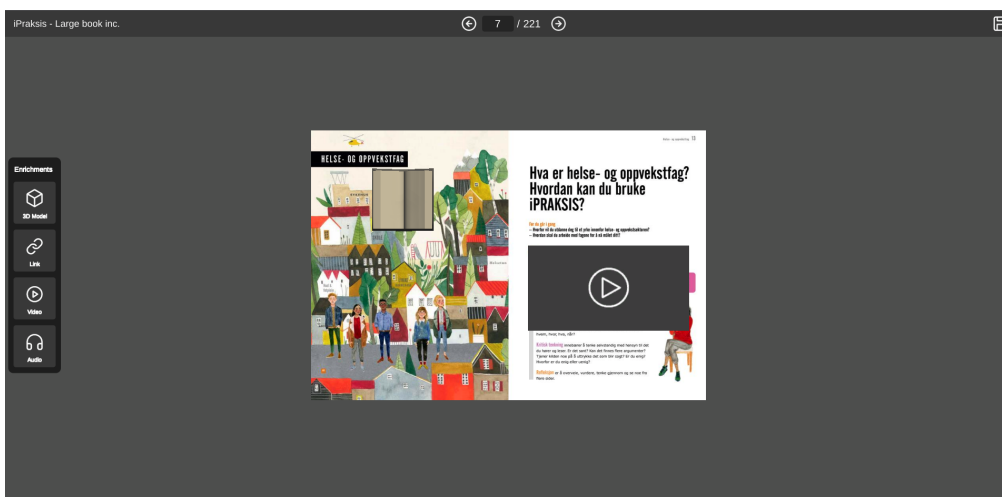
Ludenso Studio is a browser based authoring tool. The software allows the user to upload and open a pdf file (Figure 7), place and define AR content, and to publish the enriched pdf file Ludenso Explore (The mobile AR application). Some screenshots are included to further explain what the system is, as well as what it looks like at this stage.

The user uploads, or selects a previously uploaded pdf file to enrich. This is done by clicking one of the existing files in the overview, or by clicking the + button.



**Figure 7:** File overview in Ludenso Studio.

The pdf is opened and displayed to the user in what referred to as the “creation mode”. The user can now select an enrichment object from the menu at the left side of the page, and place the object somewhere on the pdf.



**Figure 8:** Creation mode in Ludenso Studio.

After the object is placed, the user can click to select the object, and define the content for that specific object. For 3d models, a 3d model library is opened (Figure 9), and for links, videos and audio enrichments, a valid link has to be added to a textfield. Videos and audio files that are to be added to an enrichment need to be hosted online, so that the file content can be streamed.



**Figure 9:** Creation view with 3d model library open.

In this version of the software, the user publishes, or sends the enriched pdf file to Ludenso Explore (Mobile AR application), by clicking the save icon. This also saves the enriched pdf file in Ludenso Studio.

### 2.1.3 Value overview before project

To gain a deeper understanding of how this service is supposed to work, one can look at the value it creates for the different actors. In order to do this, a value overview for the different actors has been created.

Actor	Value
Student	Improves learning and motivation.
Teacher	Improves student learning and motivation. Increases flexibility of books (If able to change enrichments or make own enrichments).
Publisher	Ability bridge the gap between digital and physical learning resources. Access to data on how our physical learning resources are being used. Ability to create better learning and teaching experiences for their customers.

**Figure 10:** Value overview.

### 2.1.4 Touchpoints in planned service

The touchpoint overview (Figure 11) shows the different steps the users will likely go through when using the service.



**Figure 11:** Touchpoints for different user groups.

## 2.2 Technology

### 2.2.1 Augmented Reality

Augmented reality (AR) is a technology that adds digital elements to the real world. In the 1994 article “A Taxonomy of Mixed Reality Visual Displays”, Milgram and Kishino defined Augmented reality as:

*“all cases in which the display of an otherwise real environment is augmented by means of virtual (computer graphic) objects.”*

(Milgram & Kishino, 1994).

In other words, the concept of augmented reality refers to the addition of digital elements to the real world. This is most often done through the addition of digital visual elements through a display of some sort, however, according to Azuma et al., augmented reality is not necessarily limited to sense of sight. Rather, augmented reality could potentially apply to any sense (Azuma et al., 2001). If done well, AR can create a seamless experience where the user can experience, explore, and even interact with digital objects in an immersive way. AR technology allows a combination of flexibility and immersion when it comes to conveying information (Carmigniani & Furht, 2011). The technology has the flexibility of digital solutions, where the only major limitation to what can be conveyed is what digital resources can be found and used. This information can be conveyed in an immersive way through the combination of real and virtual environments.

Today, a common way to determine where and how an AR experience is placed is through a “target”. A target serves as an anchor for AR elements in the real world, by telling the AR application where, and often also what should be displayed. One way to create these targets is through QR codes. When the QR code is recognized, the AR application knows what enrichments should be placed, and where they are to be placed.



## 2.2.2 Extended reality

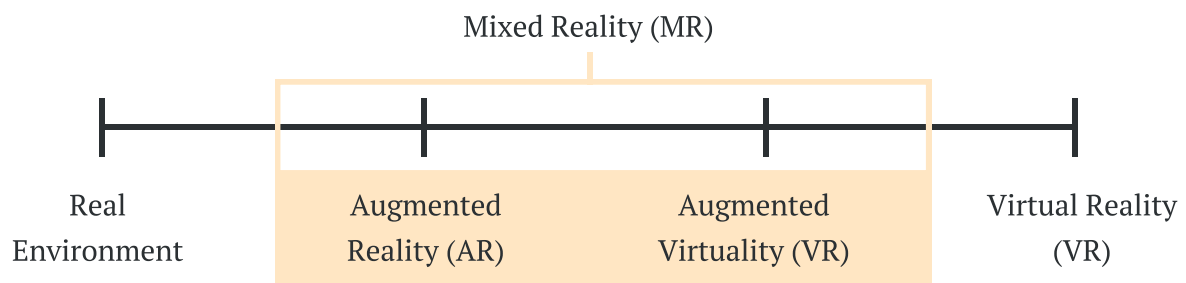
AR is a technology within the broader term extended reality (XR), which also encapsulates other technologies such as virtual reality (VR). For many people, the terminology and technologies around AR might be confusing. This subchapter will give a short explanation of the technologies within XR. XR is defined by Dictionary.com as:

*“an environment or experience that combines virtual and physical realities through the use of computer technology or wearable technologies, as in augmented reality, mixed reality, virtual reality, or any similar mediated reality”*

(dictionary.com)

As is apparent in the definition, there are several other technologies within XR, but AR and VR are the most well known of these.

The technologies within XR can be visualized on the reality-virtuality continuum (Figure 12). The continuum places XR technologies on a line going from a fully real environment to a fully virtual environment. This also visualizes the difference between AR and VR. While AR exists in the combination of real and virtual environments, VR is fully virtual, at least visually. This project focuses on AR, as this is the main technological domain for Ludenso.



**Figure 12:** The reality-virtuality continuum.

### 2.2.3 Devices

Many people think of the head mounted display (HMD), a display worn in front of the eyes, when they hear VR, XR or even AR. While HMDs are indeed commonly used for VR, AR is often experienced through a more familiar device, the smartphone. An estimate made in 2021 found that there were around 1.5 billion AR capable smartphones in use (Révész, 2021), and this number has likely grown since then, as almost all smartphones being sold today are AR capable (ARCore, 2022). This results in AR through a smartphone having a clear advantage in accessibility compared to HMDs or other AR devices.

AR through a smartphone is often called MAR (mobile augmented reality) or HMAR (handheld mobile augmented reality). Goh et al. argue that HMAR is the correct term, as many different devices could be either handheld or mobile without being a smartphone (Goh et al., 2019).

### 2.2.4 Brief history of XR

Many consider the invention of the stereoscope in the 18 hundreds the creation of the first visual immersion technology. While both the hardware and use areas have greatly changed since then, the underlying technology of visual immersion builds on the same concepts.

Ivan Southland is considered to have created the first modern head mounted display in 1966 (Carmigniani et al., 2010). For a long time, HMDs were the standard for XR experiences. There were many drawbacks to these devices, such as immobility, inaccessibility and cause of motion sickness (Mendes et al., 2019).

In the 2010s, mobile augmented reality experienced an explosive growth (Craig, 2013 (page. 219)). This was due to the many advantages HMAR has compared to HMDs. One of these advantages being the portability of HMAR, compared to a HMD, as HMAR is experienced through a smartphone. This resulted in a normalization of HMAR, through smartphone applications such as Pokemon GO and Snapchat (Paavilainen et al., 2017). For many users, the use of HMAR in these applications were their first experiences with extended reality.

## 2.2.5 AR & sustainability

Since content in HMAR is digital, popularizing the use of it in an educational context might reduce the need for physical learning material. It also helps that due to its accessibility, many users would already have access to a HMAR capable device. Content in this HMAR solution is also updatable, which means that if content was to become outdated, it can simply be changed without the need to change the used book or other physical learning resources. A reduction in the need and production for physical learning materials fits with the UNs sustainable development goal 12: responsible consumption and production (United Nations).

Research and development of educational tools can also result in improved understanding, and more efficient and motivating educational tools. Projects like this one therefore contribute to sustainable development goal 4: quality of education (United Nations).

## 2.2.6 Usability in augmented reality systems

With a technology that can close the gap between real and virtual worlds, AR and similar technologies have been hyped up a lot over the last decades. While some apps, such as Snapchat or Pokemon go, have reached great success, many feel like AR has not become the mainstream technology they were expecting it to be by now. This leads to the obvious question of why AR technologies are not more commonly used by the average person when the advantages of this technology are so apparent. Many academic articles point at the usability as a key factor to ensure the success of the technology, and one can argue that in a relatively young technology such as AR, norms around interaction and usability have not been sufficiently established yet.

*“A clear threat for the success of VR technologies is the lack of usability”* (Mendes et al., 2019).

Akçayir & Akçayir elaborate on this point, saying that in an educational context, usability also affects the effectiveness of learning (Akçayir & Akçayir, 2016). In an article from 2013, Cheng & Tsai argue that usability issues must be addressed as AR technology involves extensive user interaction (Cheng & Tsai, 2013).

### 2.2.6.1 Usability and accessibility

When working with usability, it is important to emphasize the difference between usability and accessibility. The International Organization for Standardization (ISO) defines usability as:

*“The extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency, and satisfaction in a specified context of use”*

(ISO, 2018).

Meanwhile, accessibility is defined as:

*“The extent to which products, systems, services, environments and facilities can be used by people from a population with the widest range of user needs, characteristics and capabilities to achieve identified goals in identified contexts of use”*

(ISO, 2018).

Through these definitions, one can understand that accessibility serves as a foundation for usability; if a product or service is not usable, it will be impossible to measure the use.

Therefore, in order to focus on the usability of the service at all, a foundation of accessibility has to be in place.

## 2.3 AR in education

### 2.3.1 Current status

Many research papers prove the benefits of using AR in an educational context (Radu, 2014), and there are many innovative companies working to make AR experiences accessible to the average classroom. However, the use of AR, both in education and in other domains has not yet become mainstream. According to Cubillo et al., two possible reasons for this could be the difficulty in creating AR learning experiences, as well as a lack of AR tools specifically designed for education, rather than for general purpose. At the same time, the time might be ripe for AR to start reaching its potential in the classrooms. The authors also note that the accessibility of mobile devices, combined with the interest for, and development of AR solutions can create a micro-revolution when it comes to technology enhanced learning (Cubillo et al., 2015).

### 2.3.2 Advantages

The meta-review and cross media analysis by Radu finds that AR is more efficient at teaching students certain topics when compared to other traditional educational media (Radu, 2014). Similar benefits on learning effectiveness are found in many other studies including the ones by Yilmaz et al., and Aw & Zaman (Yilmaz, 2018, Aw & Badioze Zaman, 2010). The study by Radu also finds benefits in long term memory retention, with significantly better retention in the group that used AR versus the control group. Improved physical task performance is also highlighted as a benefit, as well as improved collaboration and increased motivation among the students (Radu, 2014).

Radu adds that a “spatial contiguity effect” can be created by presenting the student with multiple representations of the same information at the same time close to each other in space. There are indications that this can improve the learning for the students (Radu, 2014).

As a digital learning tool, AR allows flexibility when it comes to what content is displayed to the user. In contrast to normal books, AR content can be changed and updated to better suit the needs of the educator or the student.

The most commonly used AR devices also provide some benefits, according to an article by M. Akçayır & G. Akçayır. These include portability, encouragement of high social interactivity, and independent operability (Akçayır & Akçayır, 2016). The authors also found an increase in collaboration skills and immersion in the learning process in the use of location based, mobile AR (Akçayır & Akçayır, 2016). In addition, they find indications that the use of AR in education can enhance learning motivation, create better understanding with the students, and enhance the students learning experience (Akçayır & Akçayır, 2016).

A study conducted by Chiang et al. found several advantages to using AR when it comes to inquiry-based learning (This form of learning focuses on developing advanced social interaction skills and a higher level of thinking through hypothesizing, exploring and observing). The results indicate advantages in learning performance, motivation for attention, confidence and satisfaction (Chiang et al., 2014). The authors owe these advantages to the “use of AR technology in linking the real-world contexts with the digital learning resources at the right place and the right time” (Chiang et al., 2014).

Cubillo et al. argue that the flexibility of HMAR can be used to create a personal learning environment for each student, allowing them to match their own personal learning rhythm. In this way, AR could be used to adapt learning to the requirements of each student (Cubillo et al., 2015).

### 2.3.3 Challenges

In order for anyone to learn through augmented reality experiences, these experiences have to be created. Yilmaz writes that a difficulty in the development of AR software for educational purposes is the creation and implementation of AR content (Yilmaz, 2018). Cubillo et al. elaborate on this, writing that

*“creating virtual content is a complex task, especially when it comes to 3D objects”*

(Cubillo et al., 2015)

and that this restricts ARs impact in the classroom.

They note that educational AR content is usually static, meaning content cannot be updated, added or removed by the teachers. Even if this was possible, it would have to be carefully implemented in a service, as most teachers would not be familiar with such a service (Cubillo et al., 2015).

Akçayır & Akçayır find in their study indications that some of the benefits from using might be caused by a novelty effect, and that this effect may diminish over time as the technology becomes more familiar to the students (Akçayır & Akçayır, 2016).

Another challenge to consider is the time usage that would be required from the teachers in order for them to become comfortable with using AR technology in their classes. There is also some planning required for the teachers in order for the AR resources to provide a large benefit (Chiang et al., 2014).

### 2.3.4 Other considerations

Liarokapis & Anderson have in their article “Using Augmented Reality as a Medium to Assist Teaching in Higher Education” created a list for requirements that educational AR systems should seek to fulfill:

- It must be a robust system
- It must provide clear and concise learning
- The educator must be able to introduce new information in a simple and effective way
- It should facilitate easy interaction between teacher and student
- The technological processes must be transparent to both the teacher and the student

(Liarokapis & Anderson, 2010)

### 2.3.5 Authoring tools

The current day AR allows the creator of an experience to convey large amounts of information to the receiver of this experience, giving a lot of power to the creator of these experiences. According to Cubillo et al., content in AR applications is usually very hard for teachers to update or change. This is due to the software used to create AR experiences being very technical, as well as a lack of libraries of virtual resources (Cubillo et al., 2015).

Jeon et al., elaborates on a similar point, noting that this results in static contents, limited amount of targets and the use of virtual objects that are designed by developers. This lack of flexibility within the service often results in discontinued use of the application (Jeon et al., 2016).

In order for AR to reach its potential within the classroom, teachers have to be involved to a larger degree in the creation of the AR content. Kerawalla et al. sum this point up nicely, saying that:

*“AR content must be flexible so that teachers can adapt it to the needs of individual children.”*

(Kerawalla et al., 2006)

Seichter et al. categorize AR authoring tools into tools for programmers and tools for non-programmers. They note that while the tools for non-programmers allow fast development, they are usually restrictive in functionality. Furthermore, they mean that allowing non-programmers to create AR experiences is a way to help AR transition into the mainstream (Seichter et al., 2008).

## 2.4 Design terminology

In order to communicate efficiently about the project, some design terminology needs to be in place. Modern design terminology as used in this project has in many ways been shaped by the book “The Design of Everyday Things” by Donald Norman. In the book he describes the terms affordance, signifier, mapping, feedback and mental model in a design context. The terms are described as follows:

### **Affordance:**

An affordance refers to what object allows the user to do. For example, a handle allows grabbing, and a button allows pushing.

### **Signifier:**

A signifier is a way for an object to tell the user about its intended use. This can for example be explanatory text on a label.

### **Mapping:**

Refers to the relationship between two objects that interact with each other in some way. For example, the buttons on a stove top. The clearness of which button relates to which burner is a result of how good the mapping is.

### **Feedback:**

Feedback is the information the user gets while or after a task is performed. Feedback is often used to tell the user whether what they did was successful or not, and to show the impact of the performed action. An example would be a change in state of a button after it is clicked, indicating to the user that the click was successful.

### **Conceptual model/Mental Model:**

A mental model is the user's internal explanation for how a system works. By creating a design that enables good mental models, the designer can help the user better understand how a system works, even if that understanding is not completely accurate. For example, the folder icon in a computer tells the user that this is a sorting system for files, allowing them to quickly get a basic understanding of how it works.

(Norman, 2013, p. 10-30)



## 2.5 Gaps in research

While the literature review has been very helpful in learning about certain topics, there are some topics that are very relevant to the project that there did not seem to be much information about. It is important to be aware of these gaps in research, as they serve as opportunities to contribute to the field. Through the literature review conducted in this project, the following gaps were identified:

- Research related to the conveying of three-dimensional objects on a two-dimensional surface.
- Research related mental models for understanding extended reality.
- Research related to AR authoring tools for non-developers. (The only significant exception being the mobile AR contents builder created by Jeon et al., which was not tested on end users).

## Chapter 3

# Method

This chapter presents an overview and general explanation of the methods used in the project. Specifics on how the methods are applied is explained in the chapter for the phase in which the method was used.

## 3.1 Literature review

### 3.1.1 Goals of this method

A good starting point for an academic project is to explore prior research conducted in the relevant fields. Through a literature review, a theoretical foundation for the project can be created. There are several benefits to using this method, especially at the beginning of an academic project. The literature review seeks to fulfill the following goals:

- To build an understanding of relevant concepts and terminology.
- To gain familiarization with the research topic to which the research will contribute, as well as contextualizing the research within this field.
- To gain insight into possible research methods to use in the project.
- To lay a foundation for comparison and analysis of results.
- To identify where there are gaps and a lack of research. This might give the opportunity to contribute to the research field by focusing potential research done in this project within one of these gaps.

(Rowley & Slack, 2004)

An important part of conducting a literature review is figuring out which articles should be included and excluded. As a means of ensuring the relevance and quality of articles for the review, as well as avoiding spending excess amounts of time on articles that prove to be irrelevant for the study, a sorting process is usually conducted. This sorting can be based on many different criteria, such as publication date and the abstract of the article. The sorting process for the literature review conducted in this project is explained in chapter 4.1.1 Literature review.

## 3.2 User involving method

In addition to a theoretical foundation, this project also includes insight gathered from user inclusion. A human-centered design process has an emphasis on understanding the needs, capabilities and behavior of a group of users (Norman, 2013, p. 8). In order to achieve this understanding, users and usability experts are involved through testing and idea generation. For this project, an iterative design process is used as it allows quick exploration, prototyping and feedback from the users. In an iterative design process, continuous user involvement is key as this allows the designer to see how the user experience changes in relation to changes done to the service throughout the process.

### 3.2.1 User tests

To create an understanding of the challenges and opportunities with the service, it is important to observe how the target users react to using it in the setting they would naturally use the service. User tests have been conducted throughout the project both to test the product in different levels of detail (starting at broader focus, like the complete system or a large part of it, before narrowing the scope and looking at specific functionality), but also to document user reactions to changes made in the product(s). Throughout the user tests, a setting similar to the setting in which the final product will be used has been strived for. The user tests conducted in this project are conducted as qualitative research, as it seeks to understand the thoughts and experiences of the participants.

The user tests are conducted by giving the participants a predefined set of tasks, and allowing them to attempt to solve the tasks. If they do not manage to solve the task, their attempted solution will be noted, and they will be asked how they would ideally solve the task before being given hints or solutions to the task. Notes are taken of the participants actions during the test.

Through systematic user testing, patterns regarding what problems are experienced will become apparent. There are many potential problems that are important to avoid when user testing. The following guidelines are in place in order to avoid these issues, and to ensure maximum benefit from the user tests.

- As a means of ensuring honest feedback from the users, it is important to establish a comfortable relationship and a safe environment for feedback. To achieve this, the users were informed that the goal of the user tests was solely to identify usability issues with the software, and that all issues that were found would be of great help to the project. The users were also informed that no personal data would be collected, and that they would only be referred to by general terms when discussing the data.
- In addition to ensuring honest feedback, it is important to encourage feedback at all. The test subjects were therefore encouraged to think out loud during the user tests, and to explain what they think when they experienced something unexpected.
- As a facilitator of a user test it is very easy to consciously or unconsciously influence the user through one's own bias. To avoid this, the users were given freedom to explore and solve the tasks themselves without influence. They were also asked to declare when they felt the given task had been completed. While it is impossible to eliminate all bias, having a clear focus on minimization of bias during the user tests will improve the validity of the results.

### 3.2.2 Interviews

Semi-structured interviews were conducted in conjunction with some of the user tests. Interviews are often used to understand different perspectives on specific subjects. In this project, the interviews were used to gain a better understanding of the specific user group, as well as discussing their experience with the software through user testing.

The interviews in this project followed a general plan for 8-10 questions. Questions were added and removed during the interview based on what had already been shared by the interviewee.

### 3.2.3 Pilot tests

The first user tests in the project were conducted as pilot tests. This method is used to identify obvious issues in the software before more time is invested in planning and conducting user tests. As this testing method is about identifying distractions, rather than improving the usability for the target user group, the tests can be conducted with anyone who has an outside perspective on the project.

### 3.2.4 Expert reviews

In addition to testing the software with end users, it is also reviewed by interaction design experts through an expert review method. An expert review is a method in which a usability expert examines a design, pointing out usability issues (Harley, 2018). In this project, the expert reviews were conducted for several reasons:

- To get a professional and more critical perspective on what usability issues exist in the software.
- Using several different methods for the same goal allows triangulation of the findings.
- To include a larger group of users in the insight of the project, increasing the reliability of the research.

The expert reviews were done by letting the expert freely explore the software, while commenting on the experience from a usability standpoint. The expert reviews in this project are conducted as qualitative insight, as the participants are encouraged to share their opinions and thoughts about the experience.

### **3.2.5 Card sorting**

Later on in the project, a card sorting method was used. This is a method used for ranking alternatives, often within many different categories. The goal of using card sorting in this project was to get data on how different solutions are ranked within different categories by the users. In addition to gathering quantitative data through the ranking, the card sorting method also promotes reflection and discussion, allowing some qualitative insight as well (Alsos & Dahl, n.d.).

The card sorting method is conducted by presenting the participants with different solutions, and asking them to rank these solutions from best to worst within different categories. The results from each ranking is noted in an excel sheet, allowing easy overview of data as well as average scores.

## **3.3 Data sorting**

### **3.3.1 Journey mapping**

Journey mapping is a method used to visualize the user experience within a service. The method can be used for many different goals, like identifying areas for improvement in the user experience. Journey mapping is used in this project as a means of creating an overview of the service from a user perspective, as well as having a foundation for discussion with the external partner.

Journey maps are created based on previous insight of the service and its relevant user(s). Most commonly, a journey map will include a user group to focus on, phases of a process and the more specific steps of the process. Based on the requirements of the project, many other aspects can be added to the journey map, such as storyboards, stakeholders and emotional journey. A journey map is created by defining the desired aspects of the relevant service, and filling in these aspects for the different steps in the service based on previous insight (Stickdorn et al., 2018, p. 44).

### 3.3.2 Affinity mapping

One way to sort data is through the affinity mapping method. Affinity mapping refers to the sorting of related facts into separate groups (Pernice, 2018). The method is often used to sort findings from an insight process, as to get a better understanding of common themes within the findings, as well as better understanding how the findings relate to each other.

An affinity map is created by exploring common themes within the data, creating “clusters” or categories within these data, and sorting the data into the identified groups.

## Chapter 4

# Phase 1 - Identifying area of focus

This phase has the goal of getting an overview of the field in which this platform is to exist through exploring published research. This will also lay the foundation for narrowing the focus of the project.



## 4.1 Methods for this phase

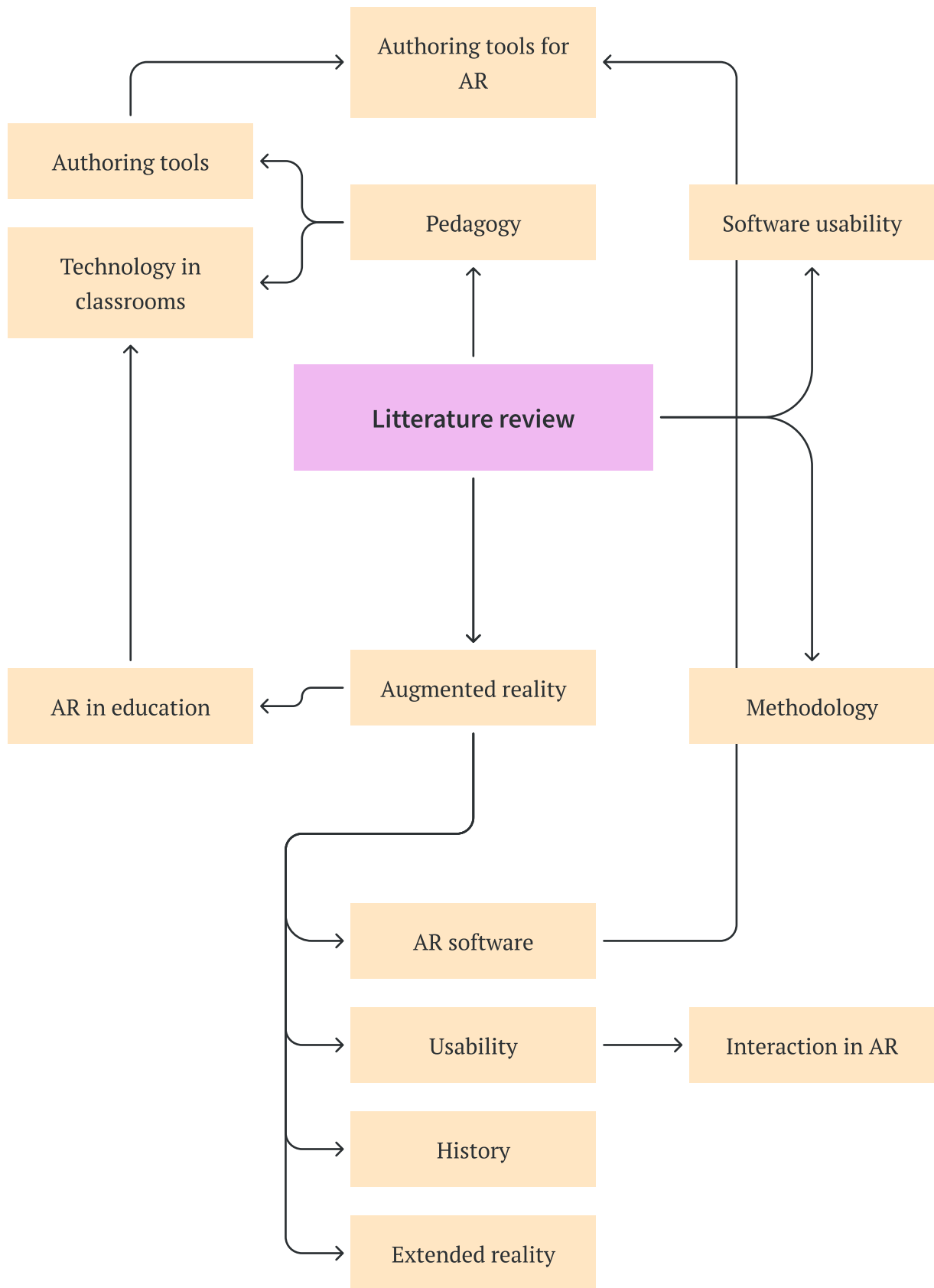
### 4.1.1 Literature review

In order to identify areas of impact, as well as getting an understanding of the field, a literature review was conducted. The review sought to include articles related to augmented reality, technology in pedagogy and software usability. The following process was to find relevant articles:

- Keywords, such as augmented reality, usability, education and pedagogy and combinations of these were searched for through the research portals Google Scholar and NTNU's Oria. Articles from the snowball sampling (step 5) were later included through this step.
- Articles were filtered by title and in some cases also date of publication. Especially for highly technological topics, newer articles were prioritized, as information quickly can be outdated.
- For the remaining articles, the abstracts were read. This resulted in more articles being excluded, as they were not as relevant as they first appeared.
- The rest of the articles were read, however they are not all included in the study, as there are cases of articles with similar or identical findings, as well as articles not fitting anywhere in the report despite their relevance.
- Snowball sampling was used with the included articles to find more articles on similar topics.

Figure 13 on the next page is a mind map of the included literature that was created with the goal of structuring the findings from the study, identifying more possible fields to be included, and organizing the included fields to understand their relationships.

The results from the literature review are included in the Background chapter. The key insight from the review is presented in the next subchapter (4.2 Key insight from literature review).



**Figure 13:** Literature review mind map.

## 4.2 Key findings from literature review

AR is currently not yet mainstream in the classroom, but a combination of factors, such as AR compatibility on smartphones might create an explosive growth in the use of AR in classrooms (Cubillo et al., 2015). However, it is still vital that the right educational tools are created.

According to the articles included in this study, there are many advantages to using AR in classrooms. Some examples are more efficient learning in certain topics, better long term memory retention and higher motivation among the students (Radu, 2014). The articles related to the use of AR in classrooms confirm that there are many opportunities for companies such as Ludenso to create educational AR tools that will have a positive impact on students' learning.

Several of the articles included in this literature highlight the lack of good authoring tools, especially authoring tools for non-developers (Cubillo et al., 2015). Many of the studies mention that the authoring tools should be usable by the educators in order to fulfill their full potential (Kerawalla et al., 2006).

The “Gaps in research” subchapter identifies several areas that are relatively unexplored by researchers. Conducting research within any of these gaps would provide a good opportunity to contribute to the field.

## 4.3 Defining area of focus

The literature review revealed the importance of non-developer inclusive authoring tools when it comes to AR platforms, especially for education. Also, there was a lack of resources and prior research related to this topic, meaning that work done on this part of the system could contribute to the field of research. These factors, as well as conversations about the project with the Ludenso team resulted in a focus being laid on this part of the system.

## Chapter 5

# Phase 2 - Pre-development

As a result of the previous phase, a focus was laid on the authoring tool of the platform. Work to improve this part of the service requires an understanding of the current status of the authoring tool. In this phase, the goal is to identify potential areas of issues within Ludenso Studio, and to understand which of these potential issues should be allocated a focus. This phase also includes an exploration of solutions for the relevant issue(s).

## 5.1 Methods for this phase

### 5.1.1 Pilot tests

In order to get the most out of the user tests with the target user group, two pilot tests were conducted using a convenience sampling method (Stickdorn et al., 2018, p. 103) before the planned user tests with the target user group. For these pilot tests, the goal was to quickly identify issues with the software that could cause distractions and pull the attention away from the software, as well as potential issues with the user test itself. Two technology students were used as the participants for the pilot tests.

### 5.1.2 User tests

After eliminating the most obvious issues and distractions within the software, user tests were conducted with the target user group in collaboration with Ludenso. The main goal of the user tests was to understand the users natural way of interacting with the software.

The users were given tasks with the goal to try all the functionality of the software, to find out what they easily understand, and what they struggle with. The plan for the user test can be found in the appendix as attachment 1. These user tests were led by me, and observed by two developers at Ludenso, to increase their understanding of the usability issues of the software. One of the developers assisted in writing down the users actions and comments. These user tests were originally planned to be conducted with 5 users, as recommended by Jakob Nielsen, as this allows identification of the most severe issues with the software (Nielsen, 2000). This was to be a combination of users involved through Ludenso and through other channels. However, due to unforeseen events (see Limitaions in Discussion chapter), only three user tests from the end user group were able to participate. This created a need for additional user based insight into the functionality of the software, which was solved by including expert reviews.

### 5.1.3 Interviews

Interviews were conducted in conjunction with the user tests described in the previous subchapter. The interview was separated into two parts, one before, and one after the user testing. The goal of the first part was to identify the participants' experience with, and understanding of AR and XR technology, as well as what digital tools they were used to, and how they work with publications. The second part focused on their experience of the software and the user test after the user test was completed. The interview guide can be found in attachment 1.

### **5.1.4 Expert review**

Expert reviews were included in the project as a means of further identifying issues with the software, and to either reinforce the validity of the issues found through user testing, or discover new additional issues that could be improved.

The expert reviews were conducted with three software usability experts. The reviews were conducted digitally, and the experts shared their screens, and were freely allowed to explore the functionality of the software while their comments were noted down. Any functionality that was not tested during their exploration was brought to their attention when they felt they were done. After the expert reviews, the different issues that were identified were sorted together with the issues from the user tests in an affinity map as described in the following subchapter.

### **5.1.5 Affinity mapping**

The results from the user tests and expert reviews are in the form of usability issues encountered through testing. As a way of organizing these findings, the issues are sorted into usability categories based on common themes within the data through affinity mapping. This was done in the digital whiteboard program Miro. The affinity map is summarized and discussed in the “Affinity Map” part later in this chapter, and added in its entirety as attachment 2.

### **5.1.6 Journey mapping**

After initial rounds of insight in the form of information from Ludenso and initial user tests and interviews, a journey map was created in order to visualize, and further understand the service from a user perspective. In the journey map created for this project, the user is an editor for a publishing house, and the goal is to enrich a book with AR content.

A journey map can include many different aspects of the user's experience. For this project, interaction channels, emotional journey and potential issues were added to each step in using the service. This allows both insight into what the process looks like, but it also serves as a foundation for a common understanding of the use of the service when discussing with Ludenso or used to identify gaps or potential issues with the current service.

## 5.2 Findings

### 5.2.1 Pilot testing results

The pilot tests helped identify many minor user experience issues that should be eliminated before moving on to more high fidelity testing. An example of a distraction that was identified is that scrolling in the 3D model library caused zooming in the page viewer. These distractions were fixed by Ludenso before the next user tests.

### 5.2.2 Interview results

The interview part was focused on understanding the daily work of the editors, as well as their experience with Augmented Reality, in order to understand the setting in which the final product was to be used. Many similarities were found in regards to the work routines of the test subjects:

- They used much of the same software such as Office products (word and excel), and digital learning material production software like for example Cloubi).
- They had limited experience with augmented reality.
- They work in similar teams, often consisting of writers, illustrators, language checkers and other editors.
- They are involved in different parts of the project, often in planning, team creation, content creation and the final composition of the book.
- They follow a similar process when it comes to creating books.

Also, the interviews gave valuable insight into how the process of creating a book worked: Most commonly, the publishing house creates the concept for the book. For textbooks, this concept is often based on public curriculum objectives. A team within the publishing house creates an overall plan for the book in regards to content and structure. A group of writers are included in the project to create the written content, and a group of illustrators work during and after the writing process to find and create fitting images and illustrations. A (mainly) external team then works on combining images and text into a layout for the book. In the final stages, the content creators, editors and language checkers thoroughly review the content of the book to ensure its quality.

According to the editors, the potential responsibility of adding AR enrichments to a textbook would fall on them, and it would probably be done after the other content.

### 5.2.3 User testing results

The user tests proved helpful in identifying issues as well as presenting potential solutions and alternatives. The software issues were immediately categorized into two categories, to help separate minor obvious issues that need simple bug fixing by the developers, and larger issues that should be solved using a design process.

From both the interviews and through observing the user tests, it is clear that the digital literacy differs greatly within the group of participants. This is important to keep in mind, as a solution should include the entire end user group, not only the most digitally competent.

**From the user tests, the following issues have been put as minor issues:**

- The user should be able to click the button of an enrichment object and click again to place it instead/in addition to being able to click and drag enrichments.
- Easier upload of pdf files (ability to drag and drop from file viewer).
- Adjust formatting of links (add www if it is not included etc).

**The following are put as issues requiring design competence:**

- A better way to convey what the system is, the relation between Ludenso Studio (authoring tool) and Ludenso Explore (Mobile AR application), as well as what AR is at all.
- The creation of an improved file overview page. Many of the users found the file overview confusing and hard to navigate.
- Better conveying how media should be added (currently only shows a field where users can paste a link to stream videos and sound).
- Improve filtering and displaying of 3d-models in the library.
- Make it easier to understand how to publish the enriched file.
- The user should be given more feedback throughout their use of the application, for example when objects are selected and when the program is loading something.

These issues, along with the ones from the expert reviews, were later sorted through the affinity map.



## 5.2.4 Expert review results

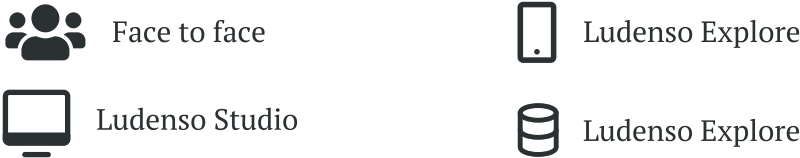
While the user tests were conducted linearly, meaning that the users were asked to test the functionality of the software in a particular order, the expert reviews were conducted in a non-linear fashion. As the test subjects in the expert reviews were allowed to explore the functionality of the software at their own pace without specified subgoals, they were very thorough in their exploration. This led to a large amount of feedback relating to the usability of the software. These comments described issues ranging from very concrete, like “There should be added buttons for zooming” to larger, more conceptual issues, such as “The system is lacking a “heartbeat”, something that lets the user know it is working as intended”. In total, the three expert reviews gave a total of 62 comments on the usability of the software.

### 5.2.5 Journey map

The journey map of the editor/user of Ludenso Studio is separated into two stages: One stage for the original creation of an enrichment file, and one stage for updating the enrichment file based on use data. The stages are broken down into interaction steps, giving a more detailed understanding of the actions being done in each stage. These steps are the foundation for defining what channels are used, understanding the user emotion, and asking the critical “what ifs”. There are obviously other steps that could be followed in the process of using the service, however, based on the insight so far in the project, the steps used in this journey map represents a common user journey.

In the journey map, it is apparent that this user group interacts the most with Ludenso Studio. Also, the lowest points of the user's emotional journey happen in the first steps of interacting with Ludenso Studio. This substantiates the decision to focus on this particular part of the platform.

In the journey maps (next page) the following icons are used to represent different channels:



**Figure 14:** Explanation of channel icons for journey map.

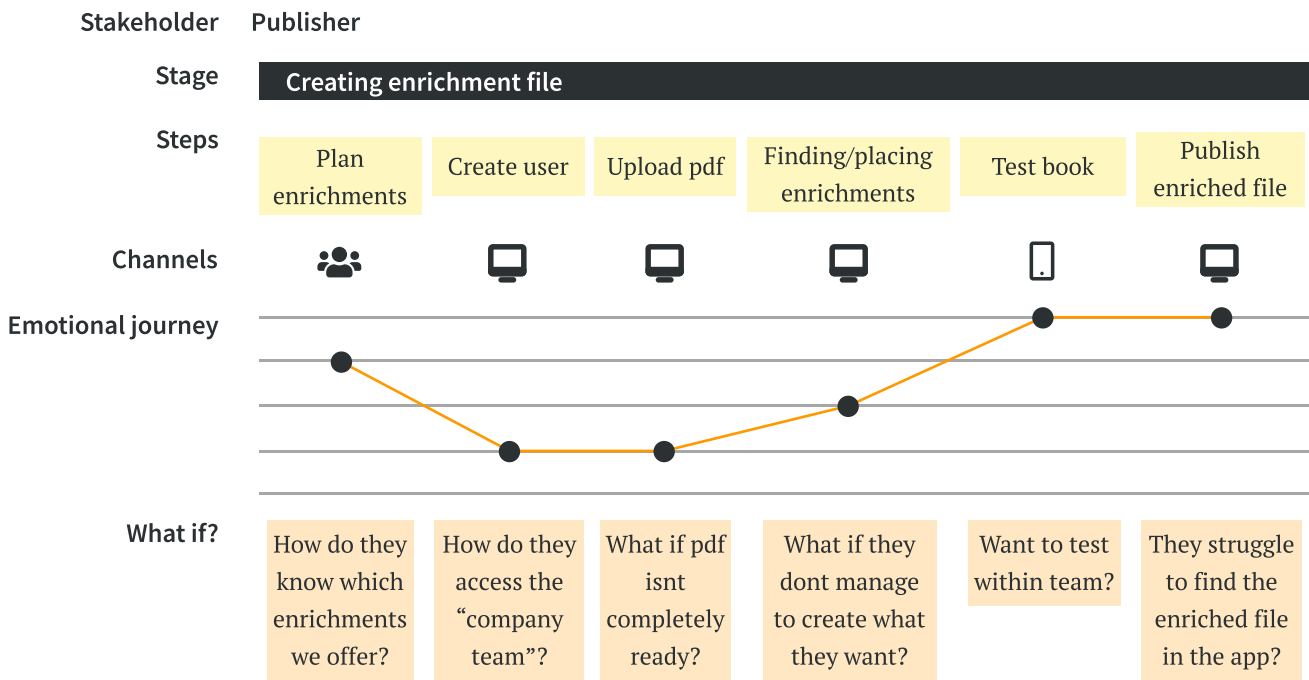


Figure 15: Journey map first stage.

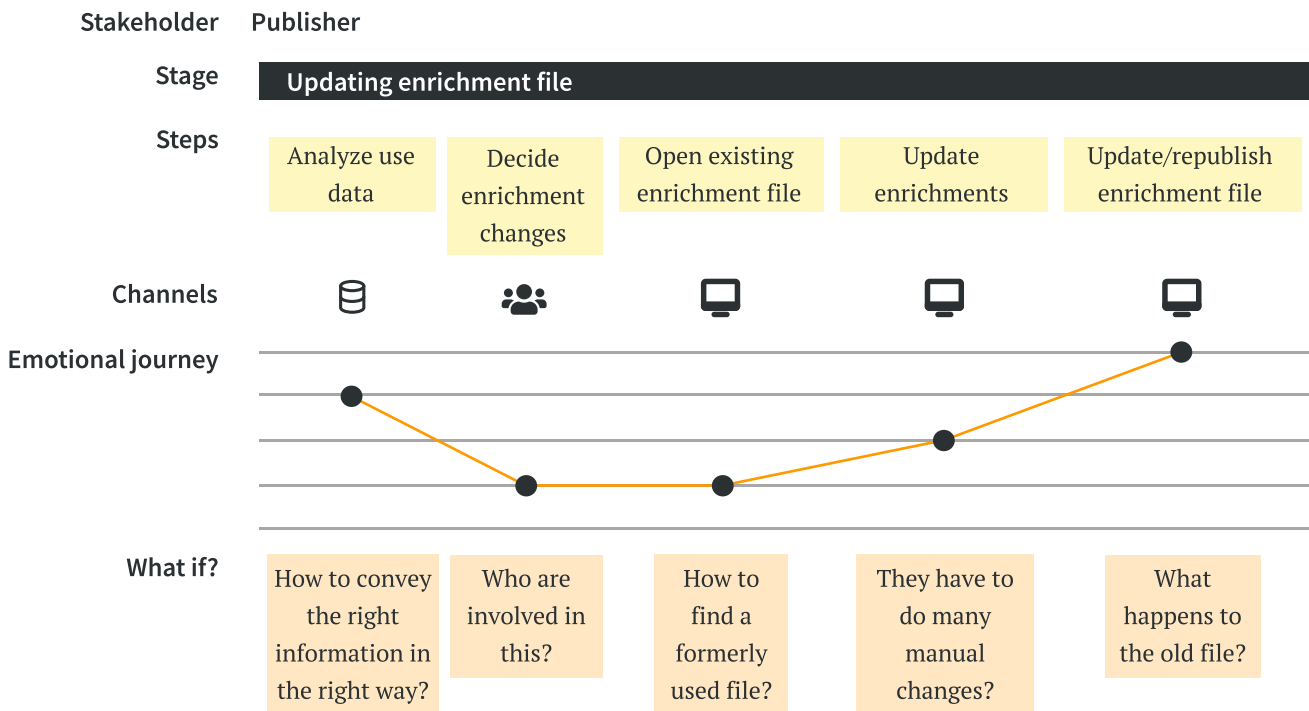


Figure 16: Journey map second stage.

## 5.2.6 Affinity map

The following categories were identified in the data, and used to sort the findings:

### **Use of language**

- How well language is used in the software? (i.e. formulations, use of terminology that is understandable for the users etc.)

### **System consistency**

- Is there consistency in the system's reaction to the user's actions? If a functionality works in one way in one part of the system, the user should be able to expect a similar reaction from similar functionality in another part of the system.

### **Feedback**

- Does the software provide effective and sufficient feedback to the users actions?

### **Mental model**

- Does the software use mental models that help the users understand how the system/software works?

### **Element affordances**

- What do the different elements of the software tell about their intended use?

### **Mapping**

- How well is information related to an element in the software connected to that element?

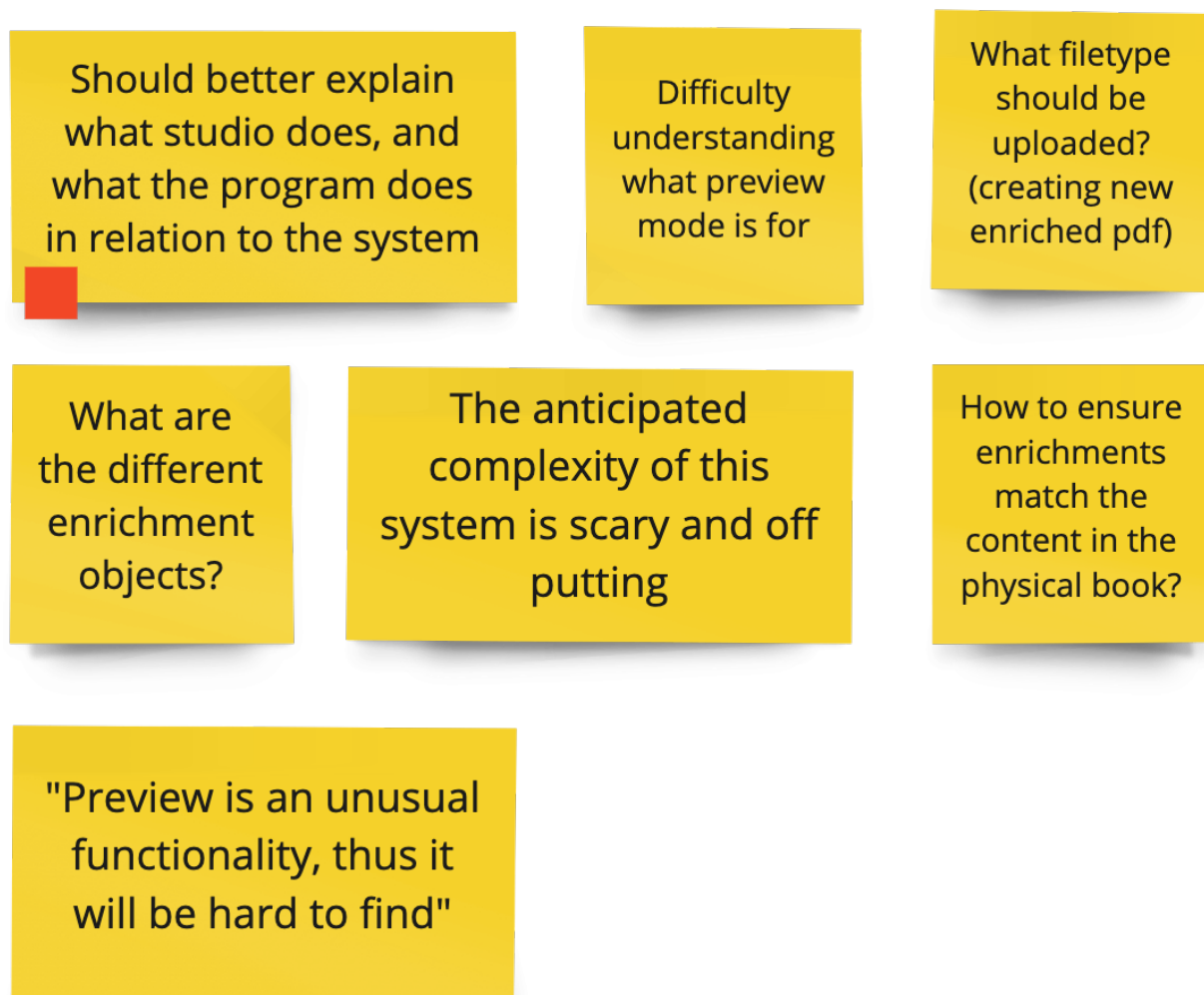
### **UI**

- How does the user interface affect the user's experience?

### **Functionality**

- How can current functionality be improved, and what functionality could be added to improve the user experience?

Figure 17 shows the mental model category and its related issues. The full affinity map is attached as attachment 2. Red squares indicate additional comments on the same issue.



miro

**Figure 17:** Literature review mind map.

### 5.2.6.1 Issues

The affinity map reveals that some usability categories have larger potential for improvement than others. Issues related to feedback, mental models, element affordances and UI stand out as having many issues related to them. The following points are made regarding poor usability in these categories:

#### **Feedback:**

- System is lacking a “heartbeat”, something that lets the user know it is working and “alive”.
- Textfield for links, videos and audio files should give better feedback when a user has added a link, possibly also allow the user to “confirm” the link (by for example clicking a button next to the text field).
- Users should receive feedback while the system is uploading a pdf. If the system gives no feedback on the progress of uploading a pdf, the user might believe the system has completely frozen.
- There is a lack of change in an element when going from “undefined” to “defined”. For example, there is no change between a link enrichment element that has not yet been given a link to one where a link has been added.
- Feedback should be given when a 3d model is loading after being selected.

#### **Mental model:**

- The program should better explain what it does, and what the desired result is from its usage (creating an enriched pdf file).
- The program should better explain what it does in relation to the Ludenso enrichment platform, particularly Ludenso Explore (Mobile AR application).
- Should be easier for the user to understand what the different enrichment types are.
- The system should tranquil users by showing them that “unusual” functionality does not mean it will be hard to use.
- The relationship between physical content (the book) and digital content (enrichments) should be more apparent.

**Element affordances:**

- Enrichment elements should be better differentiated from the pdf.
- Enrichment elements should be more “interactable”, meaning they should better convey to the user that they are possible to interact with.
- Enrichment elements need to better convey that they are movable and in some cases scalable.
- Link fields should better explain what type of link should be added.
- Should be easier to add new pdf (for example by adding the possibility to drag and drop a file).
- Should it be possible to first choose a place on the pdf, then choose which type of enrichment you want to place there?
- The different enrichment elements should better convey their possibilities for interaction.

## 5.2.7 Prioritizing usability issues

As apparent in the affinity map, the user tests unveiled a lot of issues related to the usability of the software. In order to choose which issues should be prioritized for the remainder of this project, the issues are ranked based on severity. In this case, severity means how important an issue is for the continued use of the software. For example, if an issue stops or somehow inhibits the user from continuing to use the system, it will have a high severity score. On the other hand, if the user encounters an issue, but can easily continue to use the system, the severity of the issue is low.

For issues with the same severity score, an internal ranking is created based on the familiarity of the issue/relatability to other softwares. If the issue/functionality can be familiar to the user based on other software they use, it will get a lower priority, as it is more likely that the user has encountered and resolved similar problems earlier in other software.

Based on these parameters, the issues are sorted. The following are the issues from high and medium high priority ranked by severity and familiarity:

1. The software should better explain what Ludenso Studio does, and what the program does in relation to Ludenso Explore.
2. What you see in Ludenso Studio while creating an enrichment file should match what the user sees when experiencing the enriched file through Ludenso Explore.
3. Elements should change state when they are “fully defined”, i.e. when the content of an enrichment object is defined.
4. Difference between enrichment elements and pdf should be larger.
5. Enrichment objects should more clearly show to the user that they are possible to interact with.
6. Text fields (for adding links, videos and audio) should give feedback when a link is successfully added.
7. Save and publish should be separated and differentiated.
8. The UI should be updated to seem more familiar for the users, as well as giving a better impression of the software.

## 5.2.8 Mental model

At this point, it was clear that the project would include work related to understanding the users mental models, as well as facilitating good mental models for the users. This created a need for more understanding of this particular concept. The term is mentioned in the background chapter, and defined as “A user's internal explanation of how a system works” (Norman, 2013, p. 10-30).



While this seems like a relatively simple concept, the implications of an incorrect mental model can have a large impact on how a user interacts with a system. As apparent in the definition, the user's mental model is based on beliefs, rather than facts. These beliefs can be based on incomplete facts, past experiences and intuitive perceptions. The beliefs help users create a prediction for how the system will respond to different interactions, which again helps them plan their actions (Nielsen, 2010).

A good mental model makes it easy for the user to interact with the system, as the user understands the appropriate actions required to interact with it. However, an incorrect mental model can make interaction with a system difficult and confusing, as the system responds in a way that was not predicted by the user (Nielsen, 2010). This seems to correspond with the findings from the user tests in this project.

Nielsen also expresses that:

*“What users believe they know about a UI strongly impacts how they use it. Mismatched mental models are common, especially with designs that try something new.”*

(Nielsen, 2010).

Based on this, a system should facilitate good mental models for the users to ease the interaction with the system. To accomplish this, the users mental models first need to be understood so that the system can conform to the users mental models, or the system should be designed in a way that helps adjust the mental models of the users. Nielsen recommends card sorting as a useful method when it comes to discovering the user's mental model (Nielsen, 2010).

## 5.2.9 Key findings

The primary users of the authoring tool have varied technological literacy, ranging from very low to medium. In order for the software to be usable for the entire range of the users group, a focus should be put on creating a good experience for the low technological literacy group, as the users with higher technological literacy will in all likelihood still be able to use the software.

The test subjects are facing a lot of difficulties when attempting to use the system, especially within the categories of system feedback, mental model, element affordances, UI and functionality. The issues related to mental models are the most severe for the user experience, as it causes a lot of confusion, and in extension, many of the usability challenges the users experienced.

Laying a focus on the mental model of the users is also a good way to contribute to the field of research, as little prior research has been done on mental models related to augmented reality. Also, facilitating good mental models is particularly important in softwares that are the first of their kind, as the users have few or no references to similar systems (Nielsen, 2010).

## 5.3 Ideation

### 5.3.1 Exploring other mediums

The two most important issues from the severity ranking are related to the user's mental model. In order to address this, a step back should be taken to get a critical view of the assumptions the project is based upon, especially related to the medium the software is created for.

As there are this many issues related to functionality and mental models with the user, a natural question to ask is whether a browser based program on a computer really is the best way to create an authoring tool for enriching real books with AR when the AR experience itself will happen through the camera view of a handheld mobile device.

Most of the issues related to mental models seem to be derived from the fact that the user does not fully understand the connection between the file they are working on and the book where the final AR creation will be shown, as well as what they are creating in the first place.

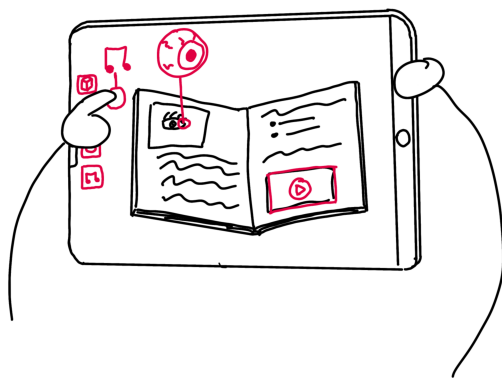
While this is probably caused by a combination of many different causes, some stand out as likely to contribute to this lack of understanding:

- The users lack of experience and understanding of what augmented reality is.
- The difference between viewing the enrichment file on the 2d screen of the computer, and viewing the enriched book in AR through the camera view in Ludenso Explore.
- The authoring tools resemblance to a pdf creation tool. While both these types of software are centered around working with pdf files, the authoring tool is strictly about adding other elements to an already created pdf file, not changing the pdf file itself.

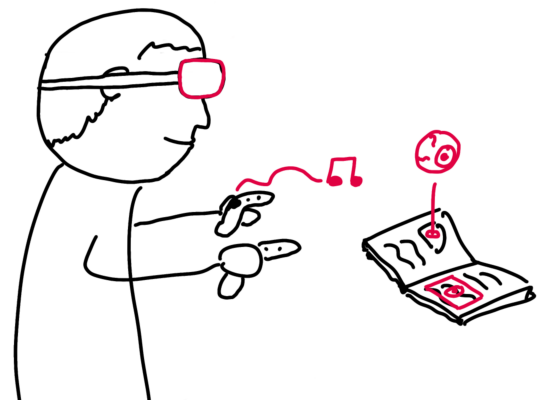
These and probably other causes contribute to the feeling of confusion the user experiences when their mental models do not match with the behavior of the software. These issues should be looked at when attempting to ease the process of creating a correct mental model for the user.

One possibility to attempt to improve on these issues is to create the software in a medium which is closer to the experience of the users of Ludenso Explore. For this idea, it is interesting to explore an authoring tool which allows the user to create AR experiences through HMAR or even through a HMD. This would allow the creator to create an experience in a manner that more closely represents the final user experiences, thus lowering the risk of an inaccurate mental model with the creator. It would also make the relation between Ludenso Studio and Ludenso Explore clearer, as the users can more easily understand what their creation will be used for.

Figure 18 and 19 show illustrations of what HMAR and HMD based AR authoring tools could look like.



**Figure 18:** Illustration of HMAR based AR authoring tool.



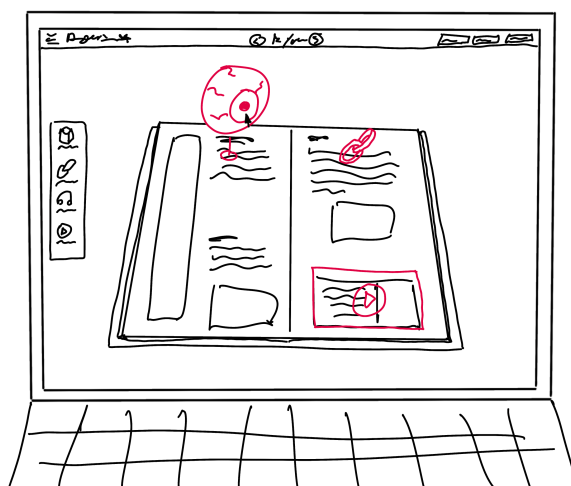
**Figure 19:** Illustration of HMD based AR authoring tool.

While such solutions obviously pose a lot of difficulties, such as hand/arm fatigue and inaccurate tracking (Goh et al. 2019), the main point of allowing the user a more accurate view is still an interesting point that should be considered regardless of the medium of the final solution.

Still, the biggest difficulty with implementing these solutions would be the lack of technical competence with the users. As found through the user tests, there is variance in the technological competence of the user group. With some of the users already being scared of the anticipated complexity of a browser based AR authoring tool, one can easily understand that they would experience trouble with creating AR experiences through HMAR or a HMD.

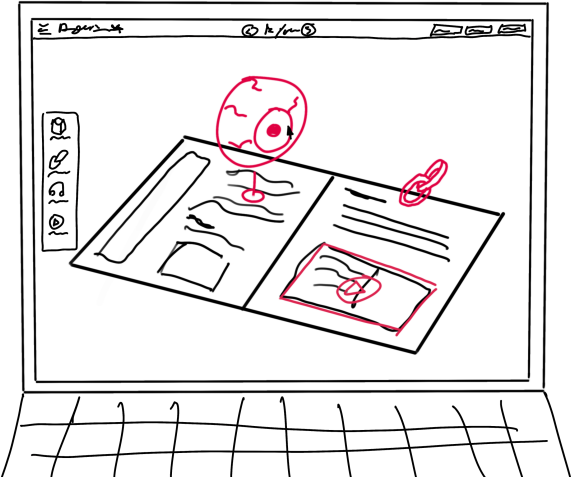
The concept of creating AR experiences through HMAR should definitely be considered in the future, as the creation better matches the final experience, and due to the accessibility of creating AR experiences only through a smartphone. However, this should be for another, more technically competent user group.

Still, ideas from these concepts could be used to inspire solutions in the existing version of Ludenso Studio. One concept that is explored is allowing the users to enrich publishing materials in a more accurate environment while still working on a computer screen. By tilting the pdf back, like laying a book down on a table, the dimension of depth is included, and the user might get a better sense of what they are actually creating. This is illustrated in figure 20.



**Figure 20:** Illustration of a perspective view in computer based AR authoring tool.

Another possibility that allows visualization of three-dimensional objects in 2d is isometric perspective. In an isometric perspective, objects are rotated and skewed to give the illusion of depth. Isometric perspective is a form of parallel perspective, meaning that parallel lines do not appear to converge towards a vanishing point. Below is an example of what Ludenso Explore could look like using an isometric perspective visualization.



**Figure 21:** Illustration of isometric view in computer based AR authoring tool.

### 5.3.2 Visualization concepts for card sorting

The final two visualization methods discussed in the previous subchapter laid the foundation for the card sorting method with the goal of finding the best visualization method to facilitate a good mental model with the users. Two more methods were added in addition to the original method of Ludenso Studio in order to have variation in the methods the participants were to rank. These are the different visualization methods that were included in the card sorting method:

#### 3d icons seen from above

This resembles the current way of showing the pdf and the enrichment elements. In this method, the enrichment objects are represented by three dimensional objects seen from above.

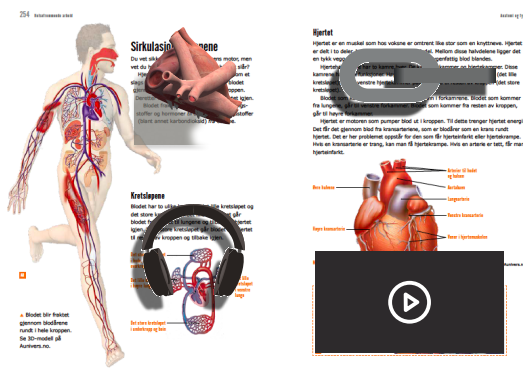


Figure 22: 3D icons in top down view.

#### 2d icons seen from above

This method uses 2d icons to display the different enrichment objects, and the pdf is seen from above.

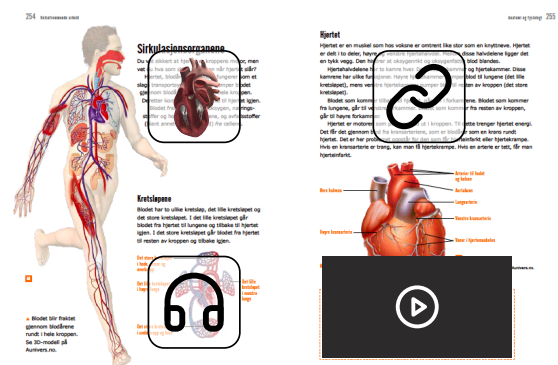


Figure 23: 2D icons in top down view.

## Text fields seen from above

The enrichment objects are represented by text fields describing the element. This method is also seen from above.

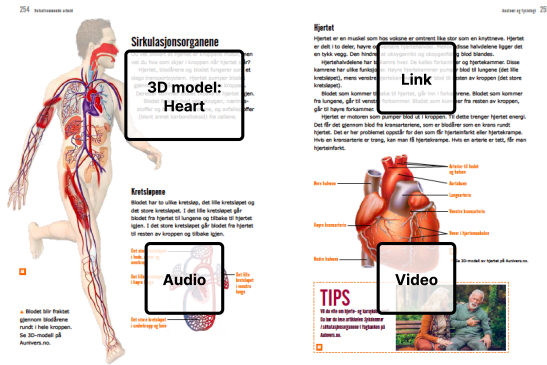


Figure 24: Text boxes in top down view.

## Perspective view

This method is made to resemble the view of the user of Ludenso Explore. The view is based on a perspective projection, where the book is tilted “away” from the user, and the sides of the book converge towards a far away vanishing point. In order to show the user where the enrichment object is in relation to the content on the pdf file, a drop shadow has been added.

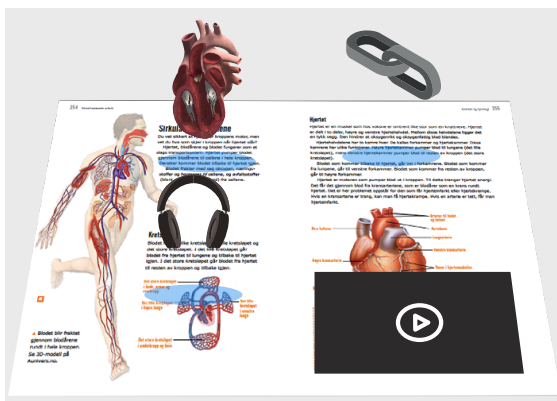


Figure 25: Text boxes in top down view.

## Isometric

In this method, the pdf is tilted and rotated to lay in a parallel perspective. The enrichment objects are hovering above the pdf, and like the perspective view, they are casting a drop shadow on the pdf.

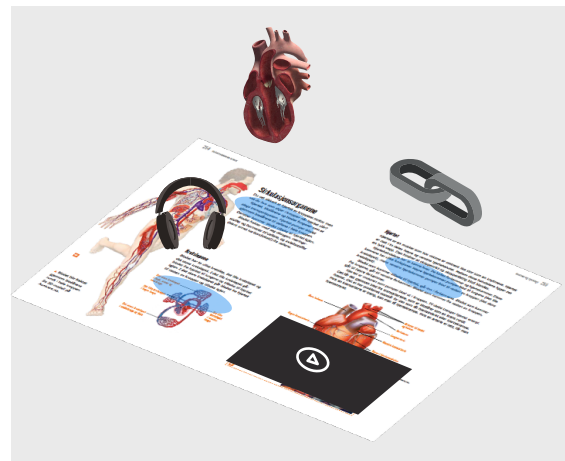


Figure 26: Text boxes in top down view.

These visualizations laid the foundation for the card sorting method used in the next phase of the project.

## Chapter 6

# Phase 3 - Testing and prototyping

It can be difficult to create solutions for problems related to usability in novel technologies. In this phase, the ideas explored in the last phase are tested as a means to understand how the usability issues can be improved upon.



## 6.1 Methods for this phase

### 6.1.1 Card sorting

In order to facilitate a more accurate mental model for the user, several alternatives to how the enrichment file is displayed during its creation have been explored. One way to test these alternatives is through a card sorting method.

In this card sorting, the different visualization methods presented in 5.3.2 Visualization concepts for card sorting are ranked within the following categories:

- Three-dimensionality
- Augmented reality
- Clarity in what the placed objects are, and where they exist in relation to the pdf.
- Resemblance to the experience of using Ludenso Explore

By finding the average ranks of the different visualizations within these concepts, one can begin to see tendencies in the mental model of the users.

The card sorting was conducted in connection with the Norwegian national conference for use of ICT (information and communication technology) in education (NKUL), which was held at Gløshaugen campus in Trondheim. The participants of the conference were a very relevant user group for the method, as there was a combination of teachers, publishers and others working in the field of education.

While obviously being very relevant for this project, the research done through card sorting also provides a good opportunity to contribute to the field of research. Through the literature review, one of the gaps that were identified were related to the visualization of three-dimensional elements on a two-dimensional display, as well as information on facilitating good mental models in XR solutions for non-developers. This means that some of the research done in this project is a novelty, as it adds to a little researched aspect in the field.

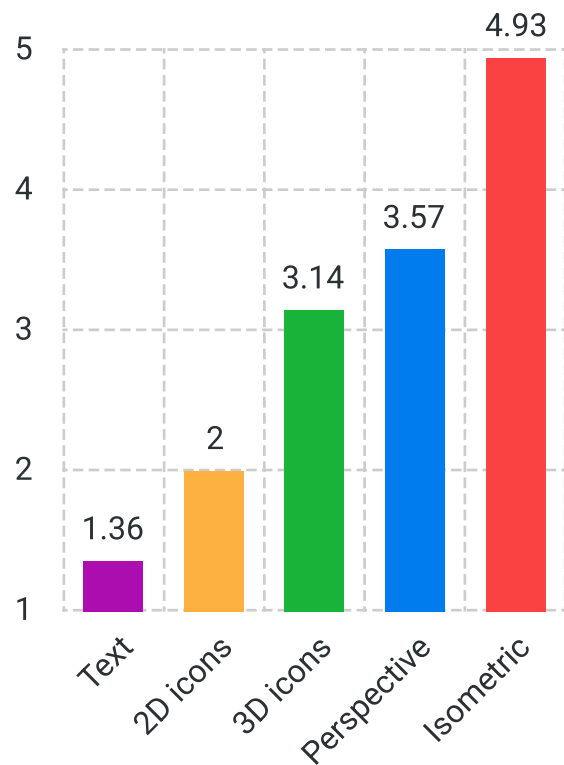
## 6.2 Findings

### 6.2.1 Findings from card sorting

The card sorting of mental models was conducted with 14 participants. The scores from this method are attached as attachment 3. The charts below show the scores of the different visualization methods within the different categories.

#### Three-dimensionality

The diagram shows that the methods are ranked in the following order, from worst to best: Text fields, 2d icons, 3d icons, perspective view, isometric view. The gaps between the different bars are relatively even, indicating a consensus among the participants as each bar closely resembles one of the possible scores, from 1 to 5 points. The only exception from this is the 3d icons view and the perspective view, being a little closer to each other than the other visualization methods. Still, the results indicate little difficulty and disagreement in ranking the visualization methods for this concept.



**Figure 27:** Average score of ranking on three-dimensionality.

### Relation to augmented reality

The diagram shows that the methods are ranked in the following order, from worst to best: Text fields, 2d icons, 3d icons, perspective view/isometric view. In this ranking, there is a clear separation between the two methods with the lowest scores (2d icons and text boxes), and the three methods with the highest scores (3d icons, perspective view and isometric view). For this ranking, the gap between the isometric view and the 3d icons and perspective view has shrunk. A possible explanation for this is that as AR is experienced from the perspective of the users, the more familiar perspectives of the 3d-icons and the perspective view resemble this perspective better.

These results also indicate that the participants mean there is a significant difference between three-dimensionality and resemblance of augmented reality. While it would be interesting to explore the cause for this difference, that is outside the scope of this project.

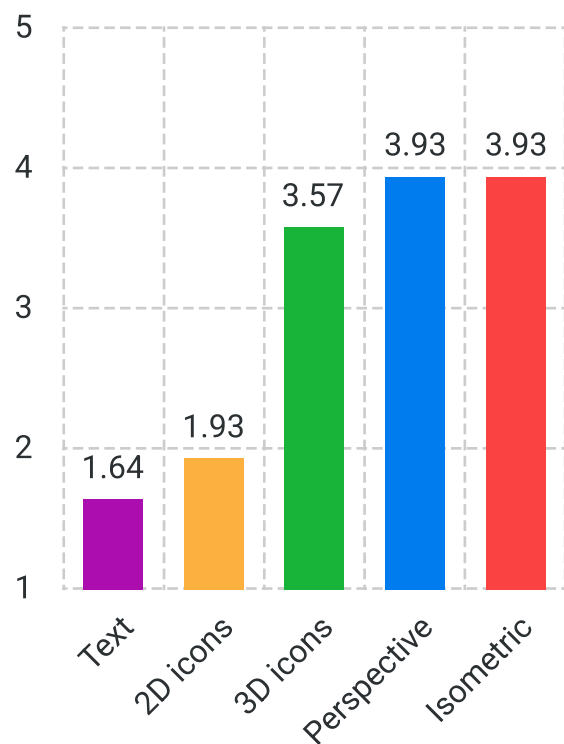


Figure 28: Average score of ranking on relation to AR.

### Clarity

The diagram shows that the methods are ranked in the following order, from worst to best: Isometric view, 3d icons, perspective view, 2d icons and text boxes. In this chart, there is little variance in the different scores, resulting in bars of similar height for all visualization methods. This could indicate a large variety in the scores given by the different participants. Still, the text box method is well above, and the isometric view is clearly below the other visualization methods.

The similarity of these scores can be caused by a combination of little difference in the clarity of the methods, and/or that this is a more subjective topic, with each participant having a different opinion on what is important for good clarity.

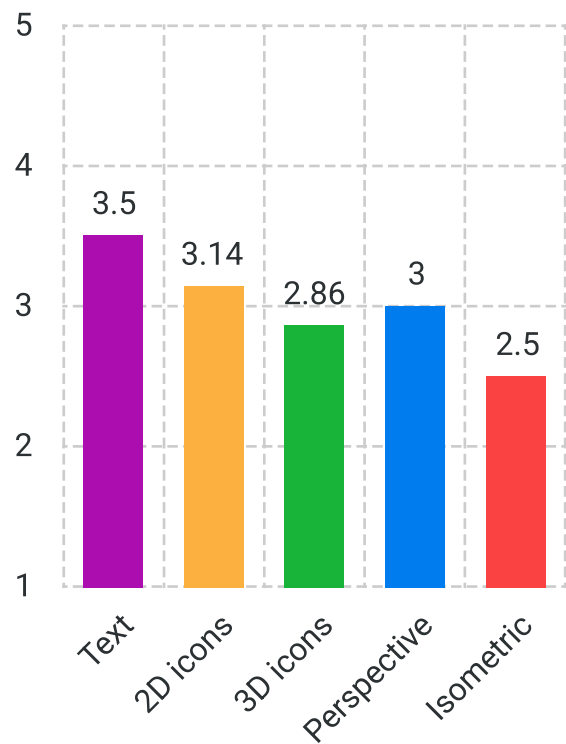
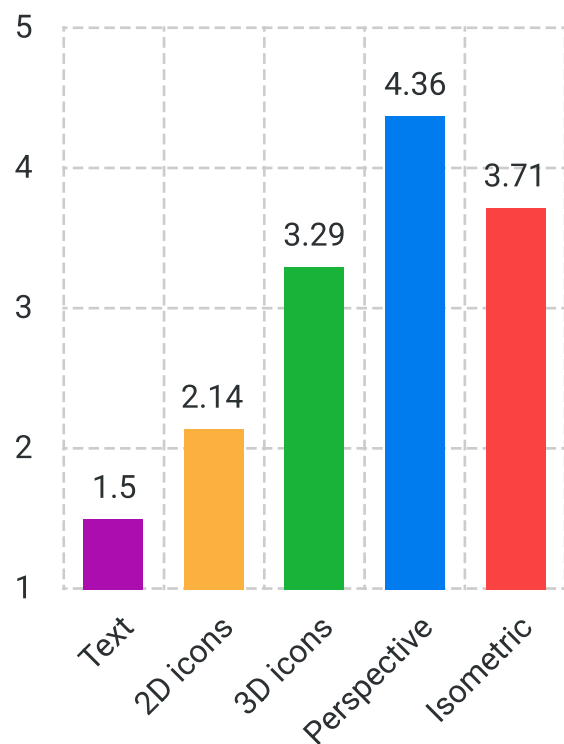


Figure 29: Average score of ranking on clarity.

### Similarity to AR experience

The diagram shows that the methods are ranked in the following order, from worst to best: Text boxes, 2d icons, 3d icons, isometric view and perspective view. Again, there are even gaps and the scores of the different methods closely resemble the possible given scores, indicating similar rankings by the participants.

In this ranking, the perspective view is ranked in a clear first place, showing that from these data, it has the biggest resemblance to the experience the participants got in Ludenso Explore.



**Figure 30:** Average score of ranking on similarity to AR experience.

### Summary of findings from card sorting

The card sorting method gives data which can be applied to facilitate good mental models for the users. Generally, the perspective view visualization method receives good scores in relation to three-dimensionality, resemblance of augmented reality and similarity to the AR experience, without a large compromise in clarity. The perspective view method was therefore used in the following prototype.

## 6.3 Ideation and prototyping

### 6.3.1 Change of perspective

As a result of the findings from the card sorting method, there were some changes made to the perspective of the pdf file when working in Ludenso Studio. The view was changed to the perspective view from the card sorting method to facilitate a more accurate and more helpful mental model with the users. The users also get a better sense of what the resulting AR experience will look like.

In this view, the enrichment objects hover above the pdf file. When selected, the enrichment object casts a projection onto the pdf file that shows the user what content on the pdf the enrichment relates to.

As a way to further increase the understanding of the users of Ludenso Studio, a book cover background is added to the pdf, creating a clearer connection between the digital pdf file and the physical book that is being enriched.

### 6.3.2 User interface

Through the previous user tests, it became clear that the user interface could do a much better job of improving the users experience with, and impression of the program. This is especially true when it comes to the differentiation of UI elements based on importance and interactability, as well as feedback from the different UI elements. To improve on this, the UI elements have been given a clearer hierarchy through placement and color. By using a saturated blue that clearly stands visually in the software, the users get a clear indication that an object is different from the rest of the UI. This can be a difference in importance, interactability or something else, regardless, the user's attention will be led to the element.

By adding more feedback to the UI elements, the user is given assurance that the system is working as intended, as well as clues as to what is happening in the system. For example, by adding hover and pressed states to buttons, the users can more easily see that buttons are clickable, and get a confirmation when a button is clicked.

### 6.3.3 Enrichment objects

Many of the issues found through the user testing related to the enrichment objects. The users struggled to understand when they were fully defined, the difference between the enrichment objects and the pdf, and even the possibility to interact with the objects. These issues pointed to a clear lack of signifiers for the objects interactability. The issues are closely intertwined, and changes made to resolve one of these issues will probably affect the other issue as well.

A common issue experienced by the users was the lack of feedback when an object was fully defined, like when a url link was added to a link enrichment object. This resulted in confusion with the users, who had to close and reopen the object to see if the link they had added was still there. To improve on this experience, the users should be given clear feedback when they have added valid specifications for the relevant enrichment object.

With the goal of increasing the perceived intractability of the enrichment objects, they should to a larger degree separate themselves from the environment in which they are placed. Also, the objects should open their definition menu when they are placed, as a way of clearly showing the user that the content of the enrichment object has yet to be defined.

When it comes to the separation of enrichment objects and the pdf, changes to the appearance of the enrichment objects should be considered. The change in perspective of the pdf also allows the users to see the y-axis (height), which should also help differentiate the enrichment objects and the pdf.

One idea to give the user better feedback and understanding when placing enrichment objects is to add the object to the mouse when they press the button to create an enrichment object. The object would then follow the position of the mouse, allowing the user to see what the enrichment object would look like on different parts of the pdf. Due to limitations with the prototyping software, this was not possible to include in the prototype.

In the prototype in the next subchapter, all the discussed issues are addressed, resulting in a solution that should cause less confusion with the users when they are using the software. In order to determine whether these changes make any difference in the experience of the users, and also to understand how the ideas can be further improved, the prototype is to be user tested and compared to the original version.

### 6.3.4 The prototype

The prototype was created in the prototyping tool Figma. The following changes are made to address the issues described in the previous subchapter:

- The user interface has been updated to look more modern and brighter. It also looks more similar to the software the user group is familiar with. Colors are used to highlight interactable and important elements, as a means of guiding the user's attention to these areas.
- Based on findings from the card sorting, changes have been made to the presentation of the pdf file. The perspective has been tilted to help the user understand that they are creating a 3d-experience, and also to give them a creation experience that is closer to the experience in Ludenso Explore. Also, a “book cover” background has been added to the pdf to indicate the relation between the digital pdf and the pages in the book.
- The enrichment object model for link and audio enrichments have been changed in order to better describe their functionality and to separate them from the pdf. The design of the enrichment objects are important to tell both the users of Ludenso Studio and the users of Ludenso Explore what they should expect from these enrichments.
- Enrichment objects now have two states, “undefined” and “defined”. The “undefined” state is semi-transparent blue, indicating incompleteness and interactability. Upon adding valid files to the enrichment object, it changes state to “completed”, which is indicated by the object changing to a solid color version.
- Enrichment object information is better mapped, and shown next to the object instead of in a separate menu (except for 3d-model library). This will help the users understand that the information is related to the selected enrichment object.
- Save and publish have been separated, and when publishing, the user gets an indication of what the published file will look like.

The prototype is created based on the assumption that the changes will improve the user experience, and reduce/eliminate the issues discovered with the previous version. These assumptions will be confirmed or disconfirmed through testing and comparison of the two versions.



Images from the prototype:

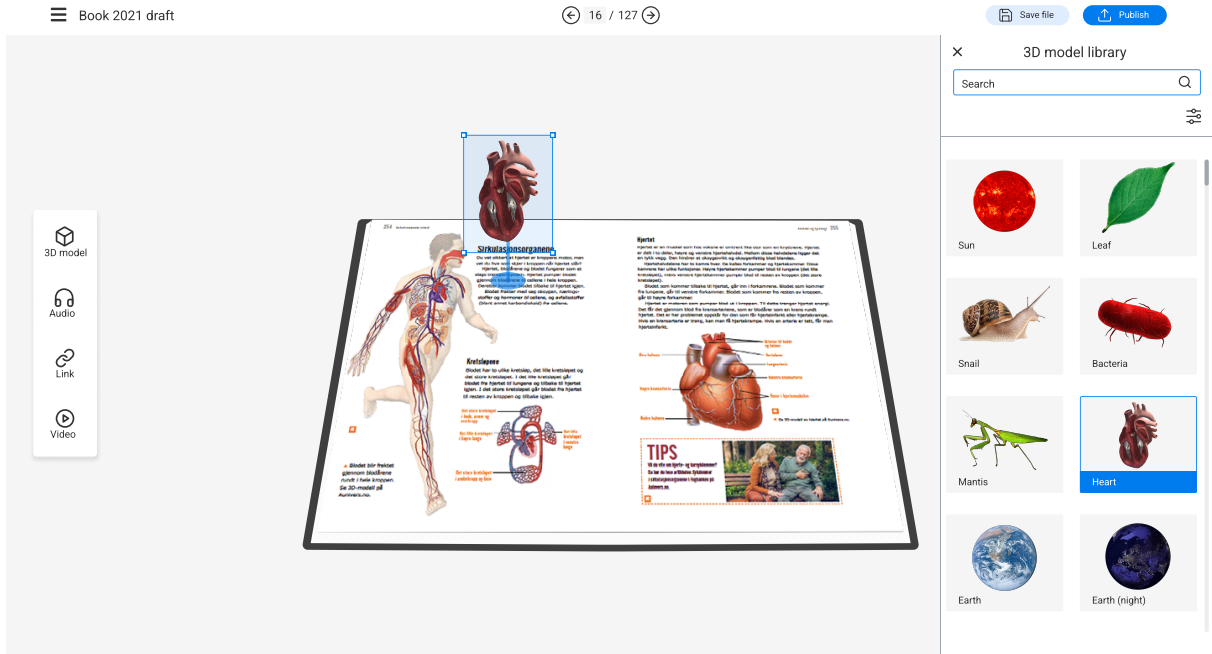


Figure 31: 3D model selection.

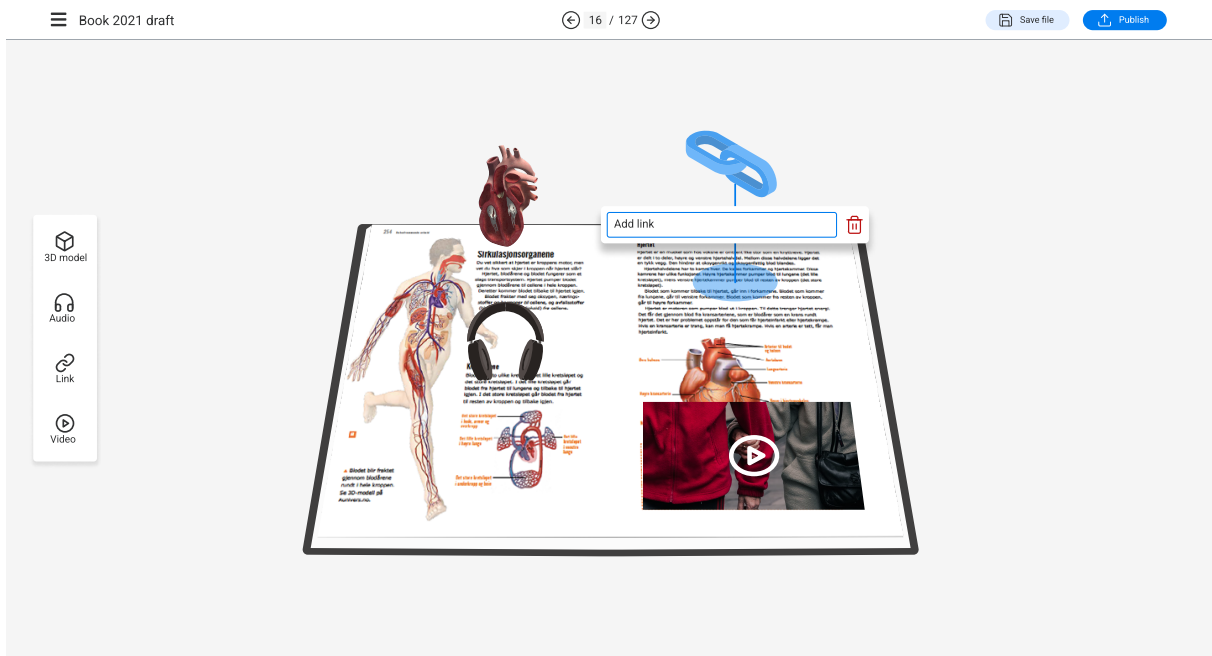


Figure 32: Book with enrichment objects.

## Chapter 7

# Phase 4 - Validation

This chapter presents the work done to validate that the prototyped new version of Ludenso Studio actually improves on the issues it set out to improve.

## 7.1 Methods for this phase

### 7.1.1 High digital literacy user tests

While much of the work done in this project is done with the goal of increasing the usability for a user group with relatively low digital literacy, it is important that the changes made do not negatively impact the experience of the more digitally literate users. In order to ensure that their experience has not been compromised, comparative user tests were conducted with a group of technology students.

The students tested the original version of Ludenso Studio, as well as the prototyped new version. After solving the given tasks in both versions of the program, they were shown the resulting experience in Ludenso Explore. This gave them a foundation to compare the two versions based on the end result. The plan for these user tests are added as attachment 4. When the user tests were completed, the users were asked to fill in the sheet for the SUS scores for each version. In addition to the statements for the SUS score, statements about the users mental model, their understanding of the software, and their opinion on the UI of the software. The following statements were added to the original SUS test:

- The enrichment file matches the end experience.
- I understand what I am creating.
- I felt confused when using the software.
- It is easy to differentiate between enrichment objects and the pdf.
- I feel certain everything I did was done correctly
- I like the look and feel of the software.

The SUS score sheet with the added statements is attached as attachment 5.

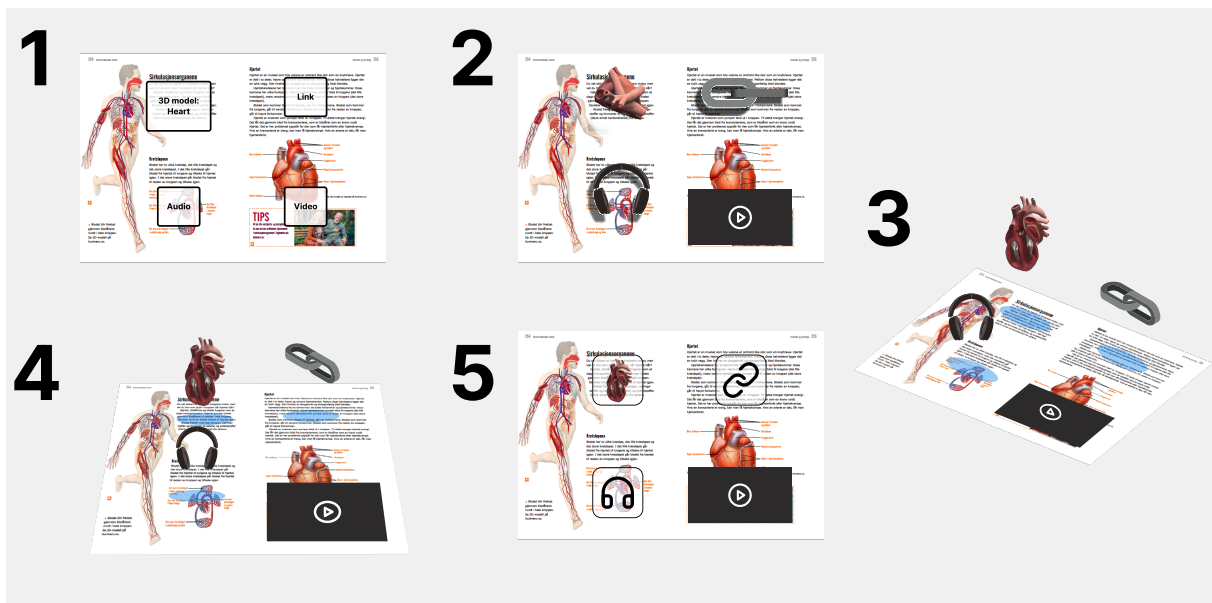
The added statements work in the same way as the original SUS statements, with users being asked to rank them from strongly disagree to strongly agree. Each value is then given a number from 1 (strongly disagree) to 5 (strongly agree). For question 3, which is negatively phrased, the score will be subtracted from 6 to give a similar score to the other questions. These scores will help determine how the changes impact the user experience of this user group. In order to reduce bias with the users, half of the test group started with the original version, and half started with the new, prototyped version.

## 7.1.2 End user group user tests

The prototype was also tested on the three participants from the first user tests. In these tests, the users were given tasks similar to the first round of user testing. Again, the goal was to test the functionality of the software, but this time, the test was focused on the functionality that had been affected by the changes. The tasks for these user tests can be found in attachment 7. These tests were also a good opportunity to get some more insight into their mental models, and more qualitative responses to their preference of visualization methods. Therefore, the users were presented with the five visualization methods from the card sorting task, and asked which ones most closely resembled the mobile AR view from Ludenso Explore, and which ones they preferred.

The prototype can be found by following this link:

<https://www.figma.com/proto/MXx8NYs9L0YcyPhBhq39IG/Prototype?page-id=0%3A1&node-id=15%3A411&viewport=-4447%2C-6097%2C0.36&scaling=min-zoom&starting-point-node-id=15%3A411&show-proto-sidebar=1>



**Figure 33:** Numbered illustration methods for user tests.

# 7.2 Findings

## 7.2.1 Results from high digital literacy user tests

The resulting scores from the SUS test can be seen in their entirety in attachment 6. An excerpt of the results is shown in figure 34. The results show a SUS average of 82.5 for the original version, and 86 for the prototype version of the software for the more digitally literate users. The average mental model score is increased from 9.8 in the original version, to 10 in the prototype version. For the confusion score, it has increased from 6 to 7.6 from the original to the prototype. The visual score is also better in the prototype version, being 9.2 compared to 8.8 in the original. These results indicate that the user experience of the software has improved since the original version.

	Original version	Prototype
SUS average	82,5	86
Average mental model score	98	100
Average confusion score	60	76
Average look&feel score	88	92

**Figure 34:** Excerpt from SUS scores.

## 7.2.2 Results from end user group user tests

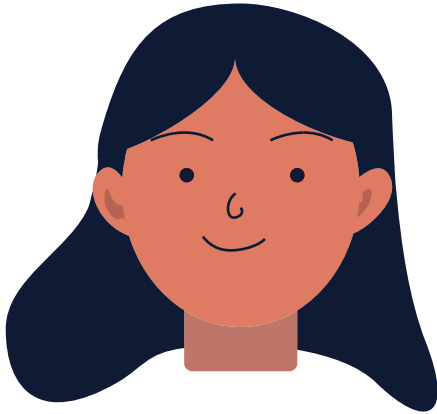
Overall, the last round of user tests went very well. The three users were easily able to complete all tasks, without much challenge. For the task related to mental models, all the participants agreed that visualization method 4 (perspective view) most closely resembled the view in Ludenso Explore, and this view was also included in their most preferred views.

While the results from these user tests seem positive to the changes made to the view of the pdf file, it is hard to say whether this was due to improved intuitiveness or simply because of the experience gained from the previous user test. While these results are from a very small sample size, the findings add to the validity of the results from the card sorting method, as again the perspective view is highlighted as being the most similar to the AR experience.

The only major concern about the visualization method of perspective view was in relation to the readability of the pdf file. As the pdf was tilted “away” from the users in the perspective used for these user tests, it became harder for them to read the text on the pdf pages.

One user noted that for more experienced users, the original visualization method (3d icons) might be better, as they had already gotten a helpful mental model, and would have a better overview of the pdf that way. The changes made to the perspective of the pdf file in the prototype has been focused around facilitating good mental models for new, inexperienced users, thus easing their process of learning the software. When it comes to productivity, it is easy to imagine that a top-down perspective would be better for the more experienced users. This is backed up by the data from the card sorting, where text boxes and 2d icons score higher than the other visualization methods when it comes to clarity.

The changes made to feedback, enrichment objects and mapping were well received by the user test participants. Based on the results from the two last rounds of user testing, some final changes were made to the prototype before delivery. These changes are highlighted in the next chapter.



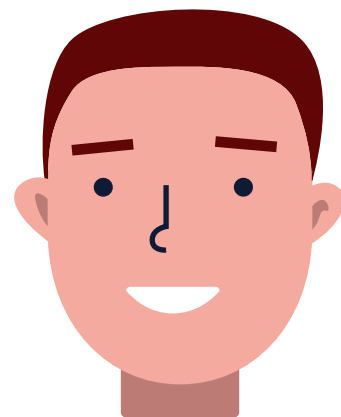
**Figure 35:** User illustration.

*“I absolutely prefer number 4 (Perspective view). It is the most similar to (Ludenso) Explore, ties the text and AR elements together, and clearly shows that it is augmented reality.”*

- Participant in user test, translated from norwegian

*“I understand why it is in perspective now, i can see the heart “floating” above the pdf, like it would in (Ludenso) Explore”*

- Participant in user test, translated from norwegian



**Figure 36:** User illustration.

## Chapter 8

# Delivery

The final delivery to Ludenso is in the form of definitions of what the software should look like based on the work done in this project. The client will get access to these definitions through a Figma file. Some outtakes are included in the following section.



# 8.1 Changes to creation mode

The final version of the creation mode does a better job of conveying what is being created by facilitating a more accurate and more usable mental model with the users.

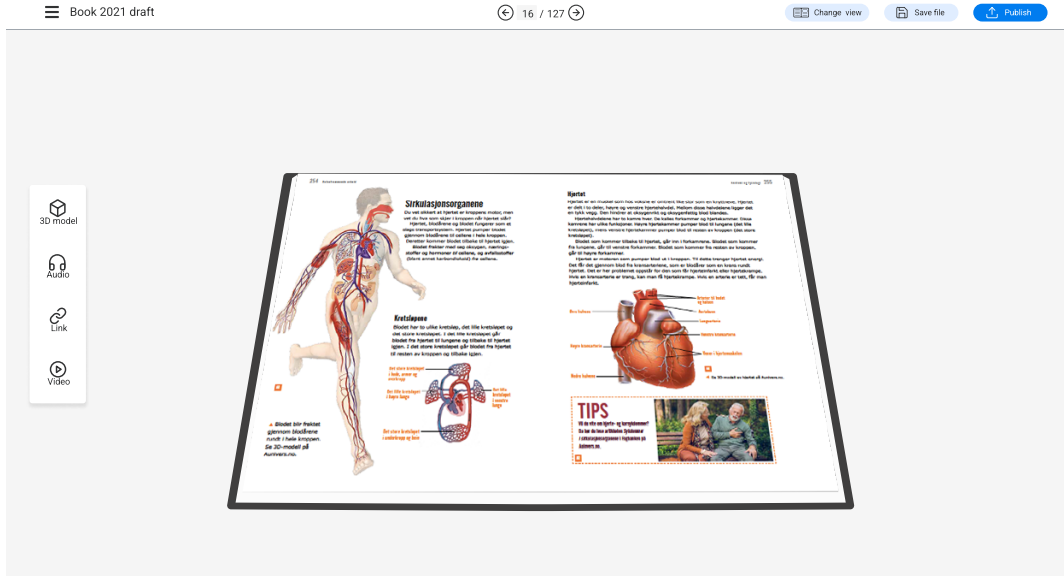


Figure 37: Pdf file viewed in final version.

The changes done to the view in creation mode are mainly done to accommodate the need of newer users. As discovered in the final user tests, some users might prefer to create through the original top-down view. The ability to switch between the two perspectives has therefore been added to this final version, in the form of a “change view” button.

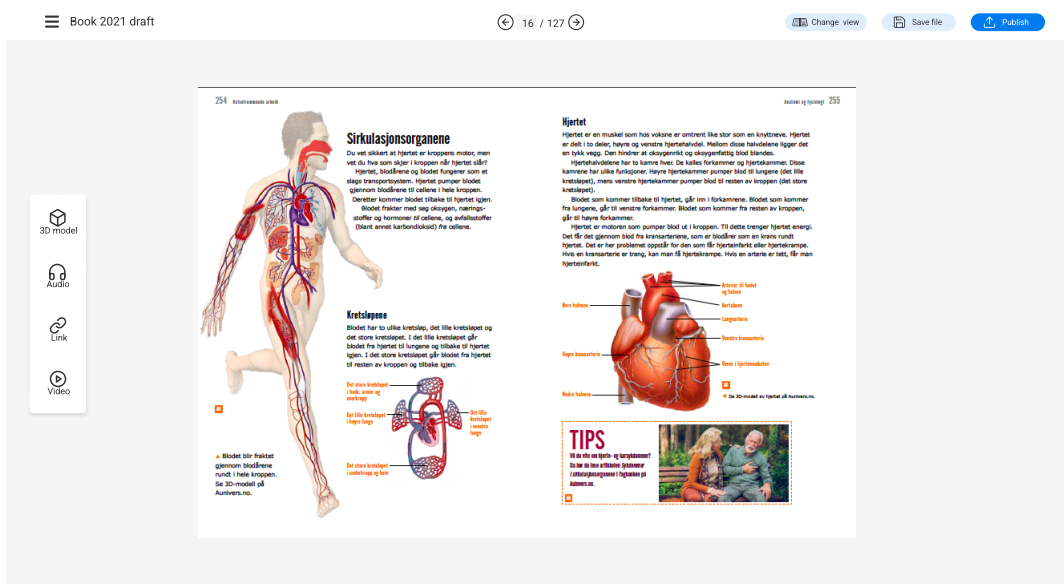


Figure 38: Top-down view in final version.

The separation between the pdf file and the enrichment objects is clearer, as enrichment objects are “floating” above the pdf.

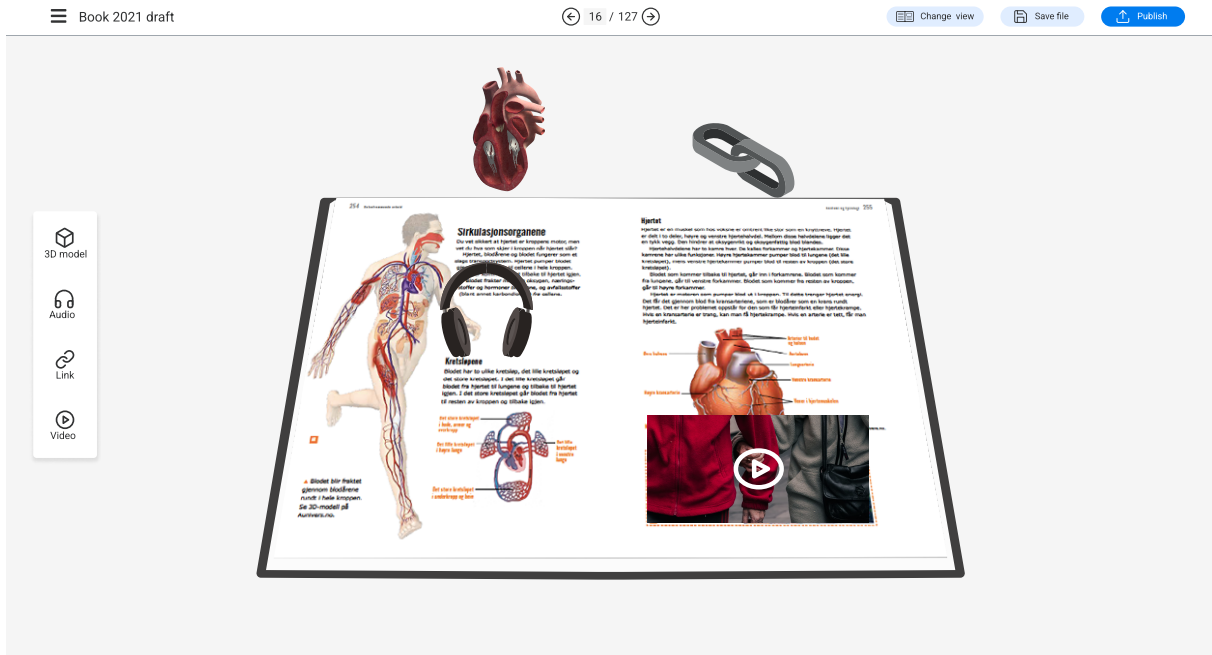


Figure 39: Pdf file viewed in creation view with enrichment objects.

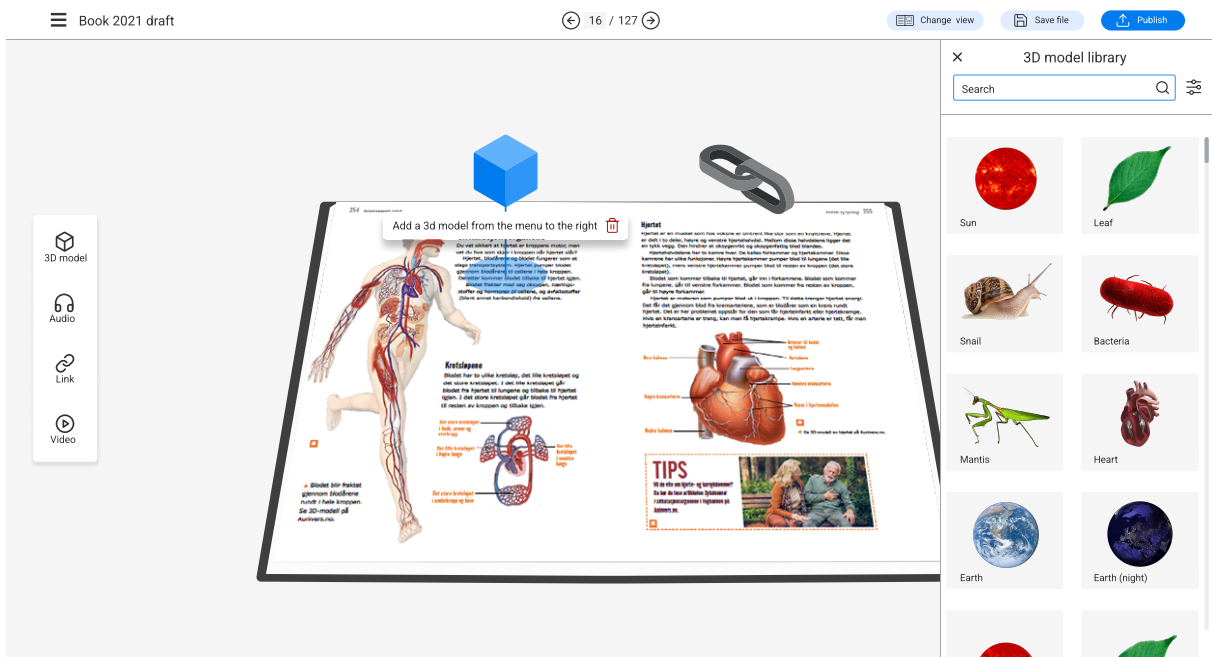


Figure 40: Choosing a 3D model.

### 8.1.1 Enrichment objects

The enrichment objects now show a clear change in state when going from being undefined to defined contentwise. The mapping between an enrichment object and relevant information/functionality is improved by more clearly connecting the information to the relevant enrichment object. The placement of enrichment objects in relation to the pdf is also clarified through the use of shadows being projected down from the enrichment objects.

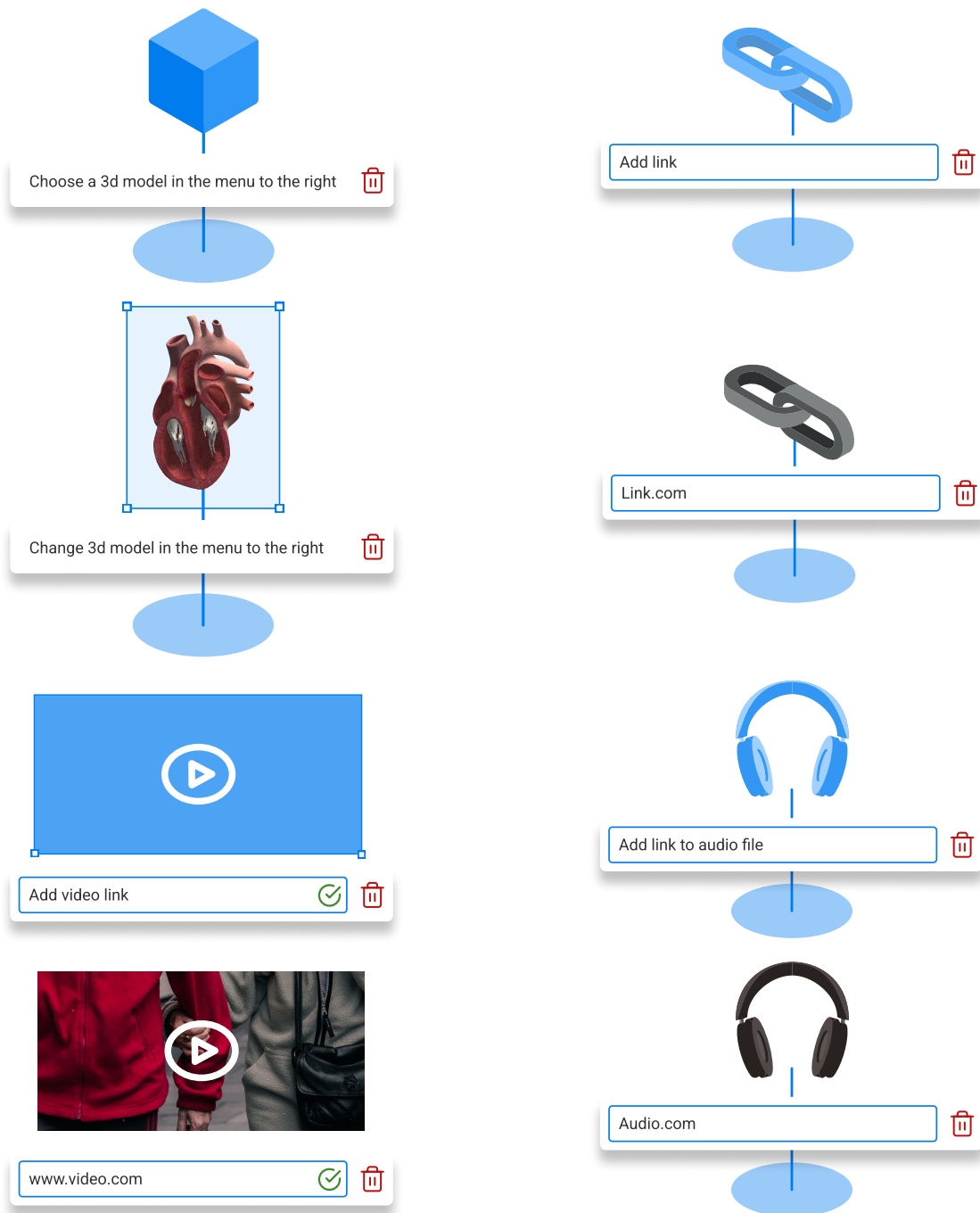
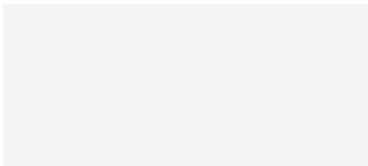


Figure 41: Enrichment objects in different states.

# 8.2 Design system

This design system presents colors, icons buttons and font in order to ensure consistency in the software, and to ease the job for the developers in Ludenso.

## Main colors



#F5F5F5



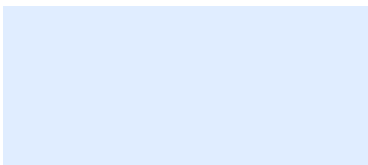
#FFFFFF



#313233



#007CEF



#E0EDFF



#9FA6AD

## Icons



Figure 42: Defining color

## Buttons

### Primary

Normal

Hover

Pressed

Inactive

### Secondary

Normal

Hover

Pressed

Inactive

## Font

### Roboto

#### Example:

Lorem ipsum dolor sit amet, consectetur adipiscing elit. Vitae in sodales et sit mattis commodo in diam urna. Molestie sollicitudin gravida amet, ac ut magna est porta amet. Nullam est, ullamcorper dui turpis lorem massa. Viverra proin eget sed vitae, gravida porta pulvinar.

## Chapter 9

# Discussion

This chapter reflects on different aspects of the project. This includes reflection on research objectives, limitations and future work.

## 9.1 Reflection on research objectives

The main goal for this project was to increase the usability of Ludensos augmented reality platform. This goal was separated into a set of subgoals.

The first goal is related to identifying and prioritizing areas of improvement within the platform. Through a literature review, the importance and lack of non-developer AR authoring tools was revealed. While many companies seek to introduce augmented reality to the classroom, the ability to create an inclusive authoring tool was a unique opportunity for Ludenso, and for me as a designer. This subgoal has been completed through conducting a literature review and based on the results, focusing the project on a critical part of the platform.

The second goal is about exploring usability and intuitiveness around the novel technology in the project. Through user inclusive insight in the first phases of the project, issues related to the user's understanding of the system became apparent. Literature reinforced the need for a basic understanding, or at least a useful mental model for the users in order to effectively use the software. Based on this, ways of creating a more accurate and useful mental model for the users were explored by using a card ranking method to rank different ways of visualizing AR enriched pdf files. This subgoal has been accomplished by researching how the software can present its content in a way that makes it easily understandable and usable for the user group.

The third goal is about applying the findings from the research conducted to improve on the usability of the platform. The findings from the mental model exploration as well as the earlier user tests were used to shape the final prototype of the software. A change in the view of the pdf file was made as a means to facilitate better mental models for the users, and other changes were made to generally improve the usability. The prototype was tested with the target user group as well as a more digitally literate group, to ensure that their experience had not been compromised by the changes. Both groups were positive to the results, and the target user group seemed to have a better understanding of what they were creating. Final changes were made to the product before sharing it with the external partner. This subgoal has been completed by creating a prototype based on the research findings, as well as testing said prototype to ensure the positive impact of the changes in regard to usability.

In summary, the goal of increasing the usability of this platform has been completed through gathering insight, developing prototypes/solutions, testing these prototypes, and delivering a final, improved version to the external partner.

## 9.2 Contribution to field

As a part of this project, research on the relatively unexplored field of mental models related to augmented reality has been conducted. While the conducted research has a low sample size, it still gives an indication on how to create good mental models related to the addition of three-dimensional objects to publications. Still, it is recommended to conduct a larger study to ensure the trustworthiness of the results.

## 9.3 Considering changes impact on system

While the work in this project has been focused on one component in Ludensos system, the changes made could have an effect on the other components, or the system as a whole. It is possible that the improvements in usability for the editors in publishing houses also have a positive impact for other potential user groups. Several of the articles in the literature review argued that educators should have the opportunity to create or customize the AR experiences they use for their classes. An increase in the general usability of Ludenso Studio is a step in the direction of creating an AR authoring tool that is accessible for educators and other non-developers.

Another result of the change in perspective made in Ludenso Studio is that as the view is closer to the view in Ludenso Explore, it could be easier to avoid cluttering of AR elements for the users of the Ludenso Explore app. With the perspective view in Ludenso Studio, it is easy to see enrichment elements that overlap each other during the creation of an enriched pdf, and adjust accordingly. This could create a better experience for the users of Ludenso Explore.

## 9.4 Limitations

While the main goals of the project have been fulfilled, it's always important to take away learnings on what could have been done differently or better both to improve as a designer, but also to be open towards the external partner. This subchapter presents areas of the project that could have been done better or differently.

### **limitations of data collection**

One limitation to the research conducted in this project is related to the number of users included. Throughout the project, three different end users have been included two times each through user inclusive methods. This is generally a very low number of target users, especially considering they represent the most important user group of the project.



There are several users for this:

- Firstly, many planned user tests had to be canceled due to sickness.
- Secondly, it was generally hard to get in contact with end users, and have them take thirty minutes out of their working hours to contribute to my project.

While much has been done to try and make up for this low number (for example the use of other methods), ideally, more representatives from the actual end user group should have been included. It is recommended for Ludenso that they continue user testing the solution on the relevant end user group.

While the card sorting method is a combination of qualitative and quantitative insight, the quantitative results (card sorting averages) proved to be the most relevant for the project. If one was to definitively say something based on these quantitative results, the study should have been conducted with a larger number of participants than the number included in this project. Still, the results from the card sorting method served as an indication, which was later validated through the last user tests.

### **Method selection**

As design is a field that offers great flexibility in selection of methods, there is a chance that one method has been chosen at the expense of another method that would be more suited for the specific task. As it is impossible to predict the results from a method before it has been applied to the project, the designer has to choose a method based on the insight at hand when the decision is made. The methods used for this project were based on the insight at the point the methods were chosen. It is entirely possible that other methods could be used to give insight of as high, or higher value than the insight gained through the actually applied methods.

### **Participant recruitment**

As Ludenso and I are the ones that have found participants to include in the research of this project, there is a chance that the selected participants do not represent the general group they are supposed to represent, and instead are affected by their ties to the conductors of the project. This could result in unreliabilities in the collected data, as participants may have had previous knowledge of the project. One way to avoid this could be to have the recruitment of participants be done by an independent third-party. This was not used in this project due to economic limitations.

### **Generalization of the findings**

When conducting quantitative research, it is easy to believe that findings gathered from a small group of participants apply to the entire group. By realizing that all research participants have different opinions and views based on their unique experiences, one can understand that findings from research conducted with a few individuals might not always be generalizable for the entire group. Issues related to generalization of findings might apply for this project.

### **Time management**

The project presented in this report was conducted over 5 months. Due to the unpredictability of a design project, it can be difficult to know how to distribute focus and time on the different phases within the project. For example, the time spent on this iterative project could easily be spent a deeper dive into the insight, by including more users, other types of experts and through an expansion of the literature review. While there were many aspects of the service that could be improved, the available time created a need to choose a problem in order to start working on a solution, rather than using endless amounts of time on choosing the perfect problem. There were also other phases in the project that had to be concluded despite the opportunity for more work to ensure the progress of the project. It is difficult to say how a different focus or time distribution would impact the project.

When working with external participants, booking and planning is also an important aspect to consider. In some cases, work on two different phases of the project had to be conducted in parallel, as a way of staying productive while waiting for meetings with external participants. This led to some of the work being left relevant after concluding a phase. It might have been possible to avoid, or at least minimize the effect of this by planning out these user involving methods further in advance.

In retrospect, I am pleased with the process and the project that ended up being done despite these limitations. I am also confident that this project will be of value to the external partner and to the research field.

## 9.5 Recommendations for future work

### 9.5.1 Recommendations for Ludenso

#### **Addressing other insight**

Through the insight phase and the user testing in this project, many usability issues were found and sorted. While only the most severe issues were improved upon through this project, the remaining insight still reveals much about the experiences of both the target users and experts in the field. It is recommended that Ludenso considers this insight when planning future improvement of the platform.

#### **Further facilitating correct mental models**

In order to help the users as much as possible when it comes to creating a helpful mental model, it could be useful to use several different approaches and areas in the software. For example, the splash screen could be used to show information that would further aid the user in creating a good mental model.

#### **Continuing user testing**

As mentioned under limitations, it is recommended that the Ludenso team keeps conducting user tests with the target user group to further identify and understand their needs.

#### **Accessibility**

It is recommended that Ludenso looks into accessibility guidelines, like the Web Content Accessibility Guidelines (WCAG). While there is currently a good foundation of accessibility in the software, it is particularly important in educational tools that the accessibility is held to a high standard. The guidelines can be found at <https://www.w3.org/WAI/standards-guidelines/wcag/>.

### 9.5.2 Recommendations for future research

This project has revealed a gap in research related to mental models in AR software for non-developers. While some data is gathered on this topic through this project, more research would be needed to get a more reliable and broader understanding of this topic. As AR is a technology on the verge of becoming mainstream, facilitating good mental models for new users is important in order to give new users a positive experience with AR solutions.

## Chapter 10

# Conclusion

The conclusion presents a summary of the project and the findings.

The main goal for this project was to increase the usability of Ludensos augmented reality platform. In order to specify this goal, it was separated to identifying areas for improvement, exploration around creating intuitivity in novel technologies, and delivering a solution that improves upon the issues in focus.

A literature review was conducted, and based on the findings, the authoring tool was identified as particularly important for the overall success of the platform. This resulted in the project being focused on this part of the platform. Through user involvement, usability issues were identified and prioritized, and different solutions and prototypes were tested. The most severe issues seemed to be tied to a lack of understanding of the system, and the creation of incorrect mental models. In addition to identifying potential for improvement in the software, this also presented a good opportunity to contribute to the field of research, as little prior research was done on mental models in this context. This led to an exploration of mental models tied to different visualization methods. Through prototype testing and card sorting, a perspective view was identified as being better for facilitating usable mental models for the users. The final solution is in the form of a prototype defined in the prototyping tool Figma, which is being shared with the external partner.

In summary, the goal of increasing the usability of this platform has been completed through gathering insight, developing prototypes/solutions, testing these prototypes, and delivering a final, improved version to the external partner.

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# Appendix

**Attachment 1 - plan and results for user tests (first round with target user group)**

**Attachment 2 - Affinity map**

**Attachment 3 - Results from card sorting**

**Attachment 4 - Plan for high digital literacy user tests**

**Attachment 5 - Modified SUS score sheet**

**Attachment 6 - SUS score results**

**Attachment 7 - Plan and results from last round of user testing**

## Attachment 1 - plan and results for user tests (first round with target user group)

### Notater brukertest 1

#### Hvilke programvare bruker du til vanlig i jobbsammenheng/hjemme?

Office word, adobe, photoshop, bridge.acrobat.

#### Er det en/noen av disse du liker spesielt godt?

Adobe

Cloubi

Ibexa

eZ

- hvorfor?

Ikke superenkle, men gøy når du lærer det

#### Er det noen av disse du ikke liker?

- hvorfor?

#### Hva er din erfaring med AR/VR?

Gjennom oss, spille gjennom pokemon go. Sønn har VR headsett

VR er at du er inni en annen verden.

AR er at du er i samme verden, men en verden oppå

AR er noe ekstra i tillegg til det man allerede har.

#### Hvordan jobber dere på en bok?

Sammarbeider med forfattergruppe.

Noen tenker photo og illustrasjoner, noen tenker med AR i baktanke, noen bare skriver, det er forskjellig fra prosjekt til prosjekt. Eksterne blir hyret inn til bilder og sy sammen.

Bøkene mine blir skrevet med tanke på det digitale, og så ble boken skrevet basert på det.

#### Brukertester:

(Start ved bokvalget)

#### Last opp bok

trykker på +.

Publisher: "hva skal det stå her?". Ser ut som en ordre om å publisere noe.

Select. Velger en ganske stor bok.

Blir litt utålmodig. tenker at det går treigt siden hun deler skjerm.

Begynner å bla i boka automatisk

#### Legg til en 3d-modell av jorden

Trykket på den. Er forvirret. Prøver å dobbeltklikke

Greier å dra den ut.

Skjønner ikke hvordan finne 3D model bilbloteket. Dro den rundt istedenfor.

Greide å velge Jorda.

## **Attachment 1 - plan and results for user tests (first round with target user group)**

Gjorde den større automatisk.  
Lett og posisjonere.  
Usikker om hun er ferdig.

### **Legg til litt om 3dmodeller/biblioteket**

#### **Legg til en lydberikelse**

Lurer på om det skal være på samme side  
Ville laste det inn fra pcen.  
Kommer fram til at det kanskje må være en lenke.  
Fint om man kunne laste den opp.

#### **Gå til neste side**

Går fint å gå til neste side

#### **Legg til en video**

Greier å legge til video. Skjønte at det funket på samme måte som audio.  
Tenker at man må lime inn en url

#### **Legg til en link til [www.ludenso.com](http://www.ludenso.com)**

Greide å legge til link. Skrev ludenso.com og ikke www.ludenso.com

#### **Slett berikelsene du har lagt til**

Var vanskelig å se, men så den med en gang. Likte den ikke. Var lite kontrast.

#### **Gå til siste side**

Gikk fint

#### **Legg til 4 berikelser til som du velger selv**

Gøy med 3d modeller, siden det var noe der.  
valgte 3 3d-modeller

#### **Endre navn på boken**

Skjønte hvor man skulle klikke.

#### **Se forhåndsvisning av boken med berikelser**

Fant det med en gang  
Brukte lang tid på rotasjon

Publiser denne berikede pdfen til Ludenso Explore

#### **Annet:**

Vanskelig å scrolle i bokvalg menyen  
Hun husket ikke å ha savet, trodde den savet automatisk.

#### **Hva er ditt inntrykk av programmet?**

## **Attachment 1 - plan and results for user tests (first round with target user group)**

Kjempegøy.

### **Var det noe som var vanskelig å forstå/utføre?**

Hun følte hun måtte lære det litt først

### **Er det noe i LS som kan fjernes/legges til/endres for at det skal gi større verdi for deg?**

Var veldig lett.

Usikker på hvordan hun skal legge til flere 3D modeller. Få inn nye. Kjøpe pakker osv.

Legge til tekst til 3D modeller.

Legge til en forklaring, eller info boks som forklarer 3D modellen.

### **Hva synes du om brukertesting?**

Var veldig gøy. Veldig spennende. og veldig nytte.

## Notater brukertest 2

### Hvilke programvare bruker du til vanlig i jobbsammenheng/hjemme?

Photoshop og illustrator. office pakken. Ibexsa og cloubi

### Er det en/noen av disse du liker spesielt godt?

Glad i photoshop og illustrator.

Ikke superbruker

### Er det noen av disse du ikke liker?

Er ikke så glad i nye ting og oppdateringer. Liker consistent UI over tid.

### Hva er din erfaring med AR/VR?

Ikke noe spesielt, annet enn å ha prøvd VR

### Hvordan forklare AR

Du får se tingen rundt deg i 3D istedenfor å se det på en flat skjerm.

Det tilpasser seg omgivelsene sine

### Hvordan jobber dere på en bok?

Forfatter gruppe på 4 personer

onsulenter som ser over det faglige

Språkvaskere

Formgiver. setter sammen illustasjoner i boken

Produksjonskordinator.

Stiles

Korrektur runder

Fornøyd => Trykk

Digitalt så ser man hva man får. Istedenfr å gi en idee til de andre.

## Oppgaver:

### Last opp pdf i programmet:

Finner den først i fil menyen.

Vil dra den over fra fil menyen

Gikk tilbake til velg skjermen. Hun trodde den ikke hadde blitt valgt.

Tenker det har låst seg.

Hvis prikken hadde beveget seg så hadde hun kanskje trodd noe annet

### Legg til en 3d-modell av jorden

Dro ut en 3d modell med en gang.

Er litt utålmodig.

Hvis ting ikke skjer, så gjør hun det om igjen.

Dette mente hun var veldig enkelt og greit

## **Attachment 1 - plan and results for user tests (first round with target user group)**

### **Slett berikelse**

Sliter med å finne slett knappen. Trenger hjelp.

### **Legg til en lydberikelse**

Synes det er viktig at det kommer oppå

Merkelig at det bare er en lydfil

Lydfilen og teksten digital vil ikke nødvendigvis matche

Vil ikke ha det på PC. Ha en medieserver eller noe sånt

### **Gå til neste side**

Dette går fint

### **Legg til en video**

Dro ut en video

Ville hatt videoer lenket til A-Univers

### **Legg til en link til [www.ludenso.com](http://www.ludenso.com)**

La inn ludenso.no

Vil markere tekst et sted i boka og legge til link på den måten.

### **Slett berikelsene du har lagt til**

- hvor er det naturlig å plassere slett knappen?

### **Gå til siste side**

### **Legg til 4 berikelser til som du velger selv**

Legger ut hjerte.

Litt utålmodig

### **Endre navn på boken**

Går fint. Skjønner det med en gang

### **Se forhåndsvisning av boken med berikelser**

Greide dette fint

Veldig kult

Vil trykke play på filmen

Lett å se hva som er lagt til

### **Publiser denne berikede pdfen til Ludenso Explore**

Trykker på lagre knappen

Går inn på skift navn.

Aner ikke.

### **Test filen i Ludenso Explore, sjekk at alt er som det skal**

## **Attachment 1 - plan and results for user tests (first round with target user group)**

**Er det noe i LS som kan fjernes/legges til/endres for at det skal gi større verdi for deg?**

Levendegjøre. 3D modeller med lyd.

Dra filen rett over istedenfor å finne den i filstrukturen

**Hva syns du om brukertestingene?**

Var veldig enkelt å gjøre

Skjønte ikke at hun måtte dra inn brikkene. Men gjør du det en gang så skjønner du det.

**Hvem ville fått nytte av dette / gjort dette:**

Ville falt hos henne.

Kanskje forfatterne.



## Notater brukertest 3

### Hvilke programvare bruker du til vanlig i jobbsammenheng/hjemme?

word, adobe (den hun kan redigere i)(bruker ikke adobe indesign) Excel. Hun vet ikke hva hun bruker, er så mye forskjellig. Ting forandrer seg så fort. Google docs. Word delt på teams.

### Hva er din erfaring med AR/VR?

Erfaring gjennom ludenso pilot prosjekt.

Ville ha VR inn i helse og oppvekst faget. Men var usikker på VR, siden man ikke kunne ha det på for lenge. Er det ressurser i skolen til å kjøpe briller.

Gikk derfor over til AR istedenfor.

Har brukt anatomiske modeller.

Brukt AR til å knytte AR til fagstoff.

Tror ikke dette er AR

### Hvordan forklare AR

Utvidet virkelighet.

Brukte Pokemon GO for å forklare.

Få figurer i som ikke hører hjemme i virklighet vist.

Hun synes det er vanskelig å forklare uten å vise det frem.

### Hvordan jobber dere på en bok?

Ideen/konseptet kommer som regel fra forlaget.

Læreplanen som gir rammene for boka.

Går deretter ut å finner forfattere

Da brukes word

Både dropbox og teams. teams har tatt over.

Eksterne bilde redaktører. Ganske stor jobb. Har en intern.

Før de leverer tekst til forgiver, blir teksten stilet.

## Oppgaver:

### Last opp pdf i programmet:

Sliter med å laste opp pdf. skjønner ikke at + er ny.

Skjønner det til slutt.

Tror hun skal legge inn link

Skjønner ikke at publisher er forlagsnavn.

Vil bruke bilder.

Hadde to faner opp og ble forvirret.

Skjønte ikke hvorfor den ikke var oppdatert på den andre fanen

lukket feil fane.

har vanskeligheter med å oppdatere nettsiden

## **Attachment 1 - plan and results for user tests (first round with target user group)**

### **Legg til en 3d-modell av jorden**

Sliter med å finne frem til ressurser.

Hun vil markere hvor hun vil ha det.

Trenger hjelp for å dra ut 3D modellen

Skjønner ikke hvordan å finne frem til model biblioteket.

Trykker på see knappen.

Trenger hjelp for å finne frem til biblioteket

Skjønner ikke hvordan biblioteket fungerer.

\* synes det er en utfordring å fylle det biblioteket

\* skjønner ikke at man skal velge jorden

\* Kjempe enkelt men ikke intuitivt

### **Slett berikelse**

Finner ikke

### **Legg til en lydberikelse**

Går fint

### **Gå til neste side**

Bla går fint

### **Legg til en video**

Går fint

### **Legg til en link til [www.ludenso.com](http://www.ludenso.com)**

Synes det ikke er intuitivt, men synes det var greit når hun skjønte det.

Skriver inn i søkefeltet og prøver å lime inn. det gikk ikke.

greide det til slutt.

Prøvde å lime inn uten å sette fokus på søkefeltet.

Får ikke høyreklikket og limet inn. bruker ikke ctrl c + ctrl v

### **Slett berikelsene du har lagt til**

Finner ikke, trenger hjelp

### **Se forhåndsvisning av boken med berikelser**

Gir opp med en gang, men finner det lett.

Sånn hun tenkte det var ovenfra stemte overens med hvordan hun så det for seg.

### **Publiser denne berikede pdfen til Ludenso Explore**

tror hun skal sende urlen.

Spør veldig mye om hjelp.

Skjønner ikke oppgaven.

Tror hun lagrer.

Da må det komme frem. siden det er to forskjellige ting.

## **Attachment 1 - plan and results for user tests (first round with target user group)**

### **Er det noe i LS som kan fjernes/legges til/endres for at det skal gi større verdi for deg?**

Trenger en knapp som heter publisere

Liker at det bare er 6 ting å forholde seg til

Ville markert først og så valgt 3D modell

Ville også ha en forklaring på det man skal gjøre første gang.

Kjempespennende med bibliotek, men ville ha en annet felt der man kan be om custom modeller.

Høyre klikk og lim inn

skjønnte ikke 5 grense

### **Hva syns du om brukertesting?**

Hun ble helt satt ut

Hun ble litt redd for lite hun viste.

var litt skremmende.

Kunne være mer spesifikt på oppgavene, hun skjønnte ikke oppgaven.

## Attachment 2 - Affinity map

### Feedback

"Heartbeat of the system" - System should let the user know that it is "alive"

Textfield should give feedback on link add

While uploading file

Lack of feedback when an element is "fully defined"/"completed"

Feedback on loading model

"system status"

### Mental model

Should better explain what studio does, and what the program does in relation to the system

Difficulty understanding what preview mode is for

What filetype should be uploaded? (creating new enriched pdf)

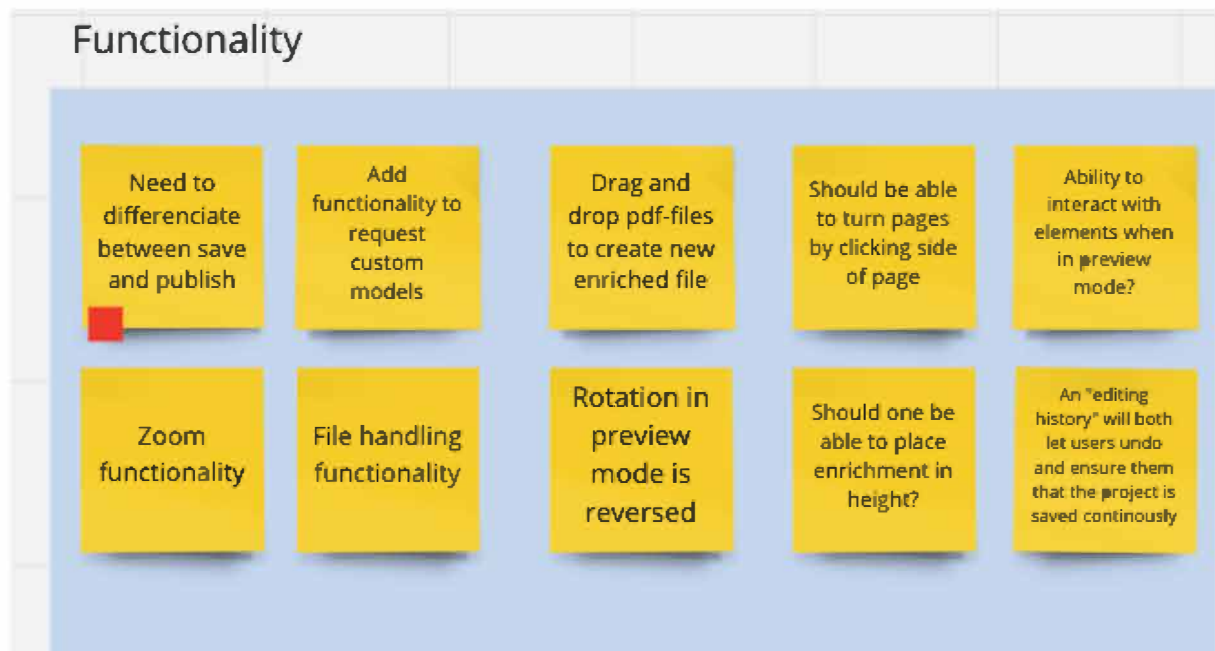
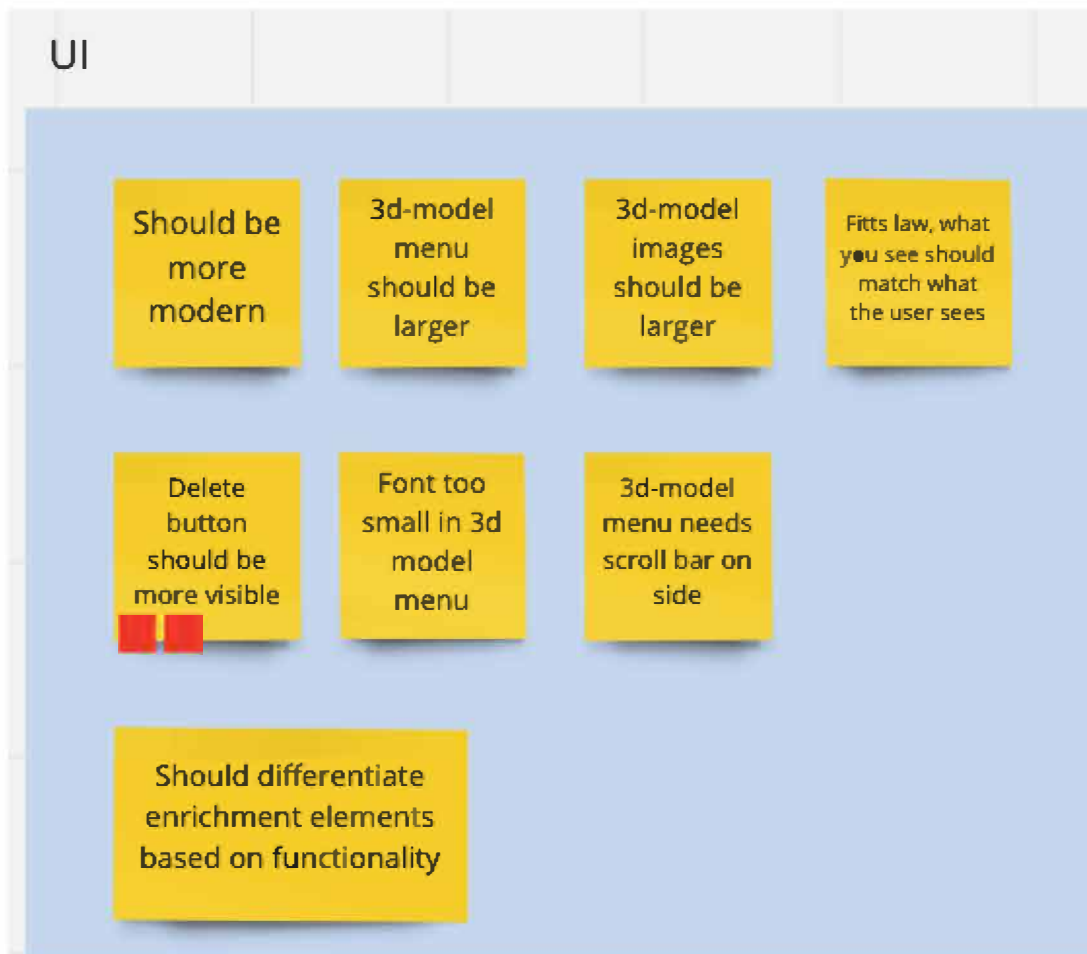
What are the different enrichment objects?

The anticipated complexity of this system is scary and off putting

How to ensure enrichments match the content in the physical book?

"Preview is an unusual functionality, thus it will be hard to find"

## Attachment 2 - Affinity map



## Attachment 2 - Affinity map

### Element affordances

Differentiating enrichment objects based on affordances

Element interactability

Element clickability

"why cant i click play in the video element?"

Lack of response and affordance

What type of link should be uploaded to the audio link field?

functionality to add new pdf should be easier to understand

wants to click page first, then select enrichment instead of vice versa

Difference between enrichment elements and pdf should be larger

What does the "standard" 3d-model mean?

### Use of language

"Publisher" what does this mean?

"Link" instead of URL in error message?

Use text in addition to icons to explain functionality

### System consistency

Scale should be consistent across pages

### Mapping

Mapping between enrichment and corresponding information

### Attachment 3 - Results from card sorting

			tredimensjonalitet	augmented reality	oversiktighet	Sammenheng med bok
	Tekst	0,76	0,92	1,96	0,84	
	Ikoner	1,12	1,08	1,76	1,24	
	3DIkoner	1,76	2	1,6	1,84	
	perspektiv	2	2,2	1,68	2,44	
	isometrisk	2,76	2,2	1,4	2,08	
1	Tekst	2	2	2		2
	Ikoner	1	1	1		1
	3DIkoner	3	3	3		3
	perspektiv	4	4	4		4
	isometrisk	5	5	5		5
2	Tekst	1	1	5		3
	Ikoner	2	2	3		4
	3DIkoner	3	4	1		5
	perspektiv	4	5	4		2
	isometrisk	5	3	2		1
3	Tekst	2	1	2		2
	Ikoner	1	2	1		1
	3DIkoner	3	3	3		5
	perspektiv	4	5	4		3
	isometrisk	5	4	5		4
4	Tekst	1	1	4		1
	Ikoner	2	2	5		2
	3DIkoner	3	3	2		3
	perspektiv	4	4	1		5
	isometrisk	5	5	3		4
5	Tekst	1	1	5		4

### Attachment 3 - Results from card sorting

		tredimensjonalitet	augmented reality	oversiktighet	Sammenheng med bok
	Ikoner	2	2	4	3
	3DIkoner	3	3	3	1
	perspektiv	4	4	2	5
	isometrisk	5	5	1	2
6	Tekst	1	1	3	1
	Ikoner	2	2	3	2
	3DIkoner	3	3	3	3
	perspektiv	4	4	3	5
	isometrisk	5	5	3	5
7	Tekst	1	1	3	1
	Ikoner	2	2	4	2
	3DIkoner	3	3	5	3
	perspektiv	4	4	2	4
	isometrisk	5	5	1	5
8	Tekst	2	1	3	1
	Ikoner	3	2	5	3
	3DIkoner	4	4	4	2
	perspektiv	1	3	2	5
	isometrisk	5	5	1	4
9	Tekst	1	1	5	1
	Ikoner	2	2	3	2
	3DIkoner	3	3	1	3
	perspektiv	4	4	2	4
	isometrisk	5	5	4	5
10	Tekst	2	4	1	1
	Ikoner	1	2	3	2
	3DIkoner	3	5	2	4
	perspektiv	4	3	5	5



### Attachment 3 - Results from card sorting

		tredimensjonalitet	augmented reality	oversiktighet	Sammenheng med bok
	isometrisk	5	1	4	3
11	Tekst	2	5	5	1
	Ikoner	1	1	3	2
	3Dikoner	5	4	4	3
	perspektiv	3	2	2	5
	isometrisk	4	3	1	4
12	Tekst	1	1	2	1
	Ikoner	4	2	1	3
	3Dikoner	3	5	4	5
	perspektiv	2	4	5	4
	isometrisk	5	3	3	2
13	Tekst	1	1	4	1
	Ikoner	3	2	5	2
	3Dikoner	2	3	3	3
	perspektiv	4	4	2	5
	isometrisk	5	5	1	4
14	Tekst	1	2	5	1
	Ikoner	2	3	3	2
	3Dikoner	3	4	2	3
	perspektiv	4	5	4	5
	isometrisk	5	1	1	4

## **Attachment 4 - Plan for high digital literacy user tests**

### High digital literacy user tests plan

**Legg til en 3d modell av et hjerte**

**Legg til en lydberikelse**

**Legg til linkberikelse**

**Legg til videoberikelse**

**Publiser filen**

**Fyll ut SUS**

**Bytt til den andre versjonen**

**Legg til en 3d modell av et hjerte**

**Legg til en lydberikelse**

**Legg til linkberikelse**

**Legg til videoberikelse**

**Publiser filen**

**Fyll ut SUS**

## Attachment 5 - Modified SUS score sheet

	Strongly disagree				Strongly agree
I think that I would like to use this software frequently.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
I found this software unnecessarily complex.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
I thought this software was easy to use.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
I think that I would need assistance to be able to use this software.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
I found the various functions in this software were well integrated.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
I thought there was too much inconsistency in this software.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
I would imagine that most people would learn to use this software very quickly.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
I found this software very cumbersome/awkward to use.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
I felt very confident using this software.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
I needed to learn a lot of things before I could get going with this software.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
The enrichment file matches the end experience.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
I understand what i am creating.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
I felt confused when using the software.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
It is easy to differentiate between enrichment objects and the pdf.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
I feel certain everything i did was done correctly.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
I like the look and feel of the software.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>





## **Plan brukertester runde 2**

**Diskusjon om visualiseringer. Hvilke foretrekker de? Hvilke er nærmest Ludenso Explore?**

**Brukertest:**

**Legg til en 3d modell av et hjerte**

**Legg til en lydberikelse**

**Legg til linkberikelse**

**Legg til videoberikelse**

**Publiser filen**

**Hvordan opplevde du denne prototypen?**

## Brukertest 1 runde 2

### **Diskusjon om visualiseringer. Hvilke foretrekker de? Hvilke er nærmest Ludenso Explore?**

Liker ikke 1, lite forklarende

Liker 3 og 4

### **Brukertest:**

#### **Legg til en 3d modell av et hjerte**

Vil først trykke og dra som i forrige versjon. Skjønner at man kan trykke og trykke igjen.

Prøver å søke etter berikelse, men dette støttes ikke i prototypen. Finner deretter i menyen.

#### **Legg til en lydberikelse**

Gikk helt fint

#### **Legg til linkberikelse**

Også helt fint

#### **Legg til videoberikelse**

Også helt fint

### **Publiser filen**

### **Hvordan opplevde du denne prototypen?**

Burde man kunne markere tekst?

Kan bli rotete med veldig mange modeller på hver side?

“Har ikke erfaring med dette, så jeg vet ikke hva jeg vil ha”

## Brukertest 2 runde 2

### **Diskusjon om visualiseringer. Hvilke foretrekker de? Hvilke er nærmest Ludenso Explore?**

Liker de hvor det svever over best, stemmer best overens med opplevelsen i appen.

### **Brukertest:**

#### **Legg til en 3d modell av et hjerte**

Prøvde først å dra den bort som i forrige versjon. Deretter går det fint

#### **Legg til en lydberikelse**

Skjønner hvorfor den er i perspektiv nå, ser at hjertet "svever"

#### **Legg til linkberikelse**

Går fint

#### **Legg til videoberikelse**

Går fint

#### **Publiser filen**

Går fint

### **Hvordan opplevde du denne prototypen?**

Jeg syns det var var veldig greit forrige gang, Kanskje man skulle kunne velge om man vil ha

Denne versjonen "ligger mer" vil ha mulighet for å lese teksten?

Kanskje liker jeg bedre at den skal være vanlig(top-down)



## Brukertest 3 runde 2

### **Diskusjon om visualiseringer. Hvilke foretrekker de? Hvilke er nærmest Ludenso Explore?**

Liker absolutt 4eren best, ligner mest på explore, knytter godt sammen tekst og AR, viser tydelig at det er AR.

### **Brukertest:**

#### **Legg til en 3d modell av et hjerte**

Hvorfor brukes det ikke tekst? "velg 3d modell i menyen til høyre"

#### **Legg til en lydberikelse**

Vil ha bekreftelse eller "godkjent" på link add

#### **Legg til linkberikelse**

Går fint

#### **Legg til videoberikelse**

Går fint

#### **Publiser filen**

Går fint

### **Hvordan opplevde du denne prototypen?**

Veldig ofte er det grået ut om det er inaktivt, det føles mer ferdig når det var blått.

Fargene har noe med ferdighet/uferdighet å gjøre, viktig å være bevisst på fargebruk.

Hadde foretrukket å markere område i pdfen først, så velge hva slags berikelse.

Vil se først, typ oversikt over hva som er gjort før publisering





